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BY THE HOUSE OF DELEGATES.

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Read and ordered to be printed.

By order,

VAUGHAN SMITH, *Clerk.*

J. HIGGINS,

State Chemist's Report.

REPORT.

In obedience to the law creating the office of State Agricultural Chemist, I respectfully submit the following Report to the House of Delegates of Maryland.

It is well known to you that in the communications which I make to your Honorable Body, that I have to call your attention and that of the people whom you represent, to such matters as in my judgment may best subserve the Agricultural interest. How that duty has hitherto been performed is answered by the testimony your predecessors have given, in ordering a much larger number of copies of my Reports each succeeding year, than was printed by the former General Assembly.

The Agricultural masses, the *people* of Maryland, require to know,—

First: the true principles of Agriculture both as to its theory and practice.

Secondly: the nature of the substances necessary to the fullest development and most economical growth of their staple crops.

Thirdly: the nature and composition of soils, and of manures, best adapted to them, and then to be shown in the last place whence to procure these manures, how to avoid imposition, and how to detect or have detected for them, the frauds which have consumed the substance earned by their honest labor.

Theory is but a knowledge of causes and effects reduced to a system, by wise and judicious codification, each effect being assigned to its proper cause, and each cause being made to show the extent of its legitimate influence, and having assigned to it the proper sphere of action to which it is entitled by its attributes.

To form a true theory then, we must first ascertain all the properties, all the adjuncts, and know the whole entire nature of the subjects which that theory treats of and determines. The subject which we discuss then, being known, we must ascertain what things have a bearing upon it, ascertain their nature both as to their mechanical and physical as well as to their vital and chemical properties; all these being known, then resort must be had to

experience and practice, *as derived from experienced and practical men themselves*, and not as given by those who profess to speak for them. That which has been done by a practical man, can best be explained by him in his own words and in his own language; the statements of many practical men can best be simplified and reduced to value by one having a familiar acquaintance with their mode of thought and expression; a wide field must be carefully examined before we can lay down special rules; the testimony of many men being competent to give testimony, in various places and at different times, must all be collected and compared before the most correct practice can be determined and decreed. That which is true of tradition or transmitted testimony, whether oral, by means of medals, manuscripts or any other kind of evidence, save that of revelation, is true as to the value of the lessons taught by experience. The same principles must be taught at all times, in all places, and by all men, otherwise they cannot be taken as a rule of action and of right, as directions to be followed or practice to be recommended.

The true theory of Agriculture then must depend upon a knowledge of the nature of crops grown for the wants of men; of the substances which enterinto their composition; the sources whence obtained, the modifying circumstances to which they are subject by human art; the nature of the soil as to its mechanical and physical as well as its chemical composition.

These being known, then the testimony of practical men must be obtained, and from them must be learned the results of their observation; and then, and not till then, can a general and universal, and at the same time a local and special system be recommended.

To carry out these views, I shall therefore proceed to give, in the first place, a description of all the substances found in our crops, specifying those obtained from the air, those from the earth, and those common to both, and afterwards the nature of the soils as to their mechanical and chemical composition; the nature and composition of various manures or fertilizers, the best mode and proper places for their application, as furnished by the testimony of observant practical men, and a knowledge of the several properties of each as far as these have been ascertained.

I deem this of more consequence at the present time, as I have received very many applications for my former Reports, each containing only *a part* of the above matter; advertisements have appeared in the papers for them, and numerous applications have been made to me in person. But there is another and a strong reason: there has lately appeared a Report from a high source, commending itself to public belief by reason of the place from whence it emanates, containing so many errors on the subject

of manures, that I feel it due to the people of our State to preserve them from the mistakes and omissions found in that Report, by furnishing them the truth in this one.

The public now demands scientific truths that they may apply them to the practical purposes of life, and to meet this demand many and various books and articles on scientific subjects, as applicable to Agriculture, have been published of late; some of these good, many bad, most indifferent. The public demands information on these subjects, and with despotic imperiousness it must be obeyed. The Farmers and Planters of our State are so well educated and intelligent a class, that they only need to know the elementary truths that belong to their calling, and they themselves can work out and practice the practical details; those facts which require technical skill to elucidate they are not expected to know, but in all that pertains to mere application as to cultivation, they are the best teachers themselves; they need no instruction, from other sources.

There is, however, an intimate connection between all the arts and sciences, and no one art has ever flourished without scientific aid: most important is it then that the most ancient and universal art should receive the aid of the oldest and most useful science. One of the first records we have is that Adam was driven from Paradise and condemned to earn his bread by the sweat of his brow, to till the soil for a support—and almost the next record we have is that *Tubal* Cain was an expert in Chemistry, having the abilityto separate metals from their ores, to combine them as alloys andto fashion them into various useful shapes; all these being the result of chemical operations.

Most interesting would it be to trace out all the connections between the arts and sciences, their mutual relations and nice dependencies. Nature does not map herself out into metes and bounds, and isolated compartments, as we classify her. We, in our weakness, do this, and mar her divine beauty by lines scrawled over her person to assist our weak minds in her comprehension. Our limited intellects cannot grasp her majestic grandeur and we have to study her by piece-meal.

The combined study of the air and what it contains, the earth and its constituents, have a direct decided bearing on agriculture, and the latter can neither be studied nor practiced to the greatest advantage without a knowledge of the former.

The Air or Atmosphere, besides containing substances having a direct influence on life by their constituent parts, has many mechanical and physical properties, aiding vegetation. It is the investing covering of the earth, one of the forces which keep things in a state of rest and give them form and support. Annihilate or even lessen it, and we would have one sea of vapor,

and a barren, icy earth; nothing would maintain its present form, the fibril of the most delicate flower, as well as the trunk of the oak, would be destroyed; it, moreover, serves as a medium for the conveyance of moisture to plants, coming down in the shape of dew from heaven, and blessing the plant beneath; moisture also exists in an insensible condition in the atmosphere, and in this state conduces to the health and growth of vegetation, even in the dryest weather a large quantity is always present and serves most important purposes. The importance of the dew and of the insensible moisture of the air may be estimated by the immense quantity of water which it represents. It has been calculated that only half of the rain that falls in the great St. Lawrence basin, passes of over Niagara Falls, the balance escapes in the form of vapor and is scattered by the winds all over the earth; which being condensed would make a river as large as the Niagara. It also serves as a conductor of electricity, whose influence upon vegetable, as well as animal life, future researches will have to develop. It may be asked of what use is all this?—Let us know the nature of the blessings which surround us; let us search into all the ways by which Providence contributes to our happiness, and whilst that knowledge will improve our physical condition, it will ennoble our moral faculties by directing them to Him " from whom all blessings flow."

So far in relation to the physical benefits of the Atmosphere, but there are others which are æsthetic; it transmits and it conveys sound. Without it no sweet music could strike upon the listening ear, no words of love could stir the still depths of the heart, there could be no voice for prayer, none for praise. The melody of bells, with all their changeful voices, could no longer speak to the human soul, and all the sweet associations that hover around accustomed sounds would be in bleak desolation. No organ tones could awake devotion, no choral voices could ascend for mercy to a throne of grace; silenced alike the wailings of the *Miserere* and the exultant harmonies of the *Te Deum*.

I now proceed to give a short description of the different substances which are necessary to vegetable life.

ORGANIC AND INORGANIC MATTER.

Upon an examination of any or all of the organized products of the earth, there are invariably found two kinds of bodies sufficiently distinct in their general and special properties as to be arranged under two separate and distinct classes, the one of these classes includes Organic, the other Inorganic matter; the former having its form easily and rapidly changed by heat, or by the slow

process of decomposition; the latter being more fixed and not susceptible of change by causes which entirely destroy the combinations of the former. Let a piece of wood or straw, grains of wheat, or any other vegetable substances be exposed to a red heat, with free access of air, and we find, after a certain time, that their forms are changed, their bulk very much diminished, and a large proportion of their weight dissipated, there being left behind only a small quantity of what are commonly called *ashes*. These are the inorganic, or mineral, whilst the parts which have disappeared are the *organic* constituents of vegetable structure.

The part which has disappeared in the air is that portion of plants which was almost entirely obtained from the air during their growth, the part remaining and called the ashes, that which composes the inorganic or *mineral part*, is that portion furnished *entirely* by the soil, because it does not and cannot exist in the air.

The part which is dissipated by heat, called organic or vegetable matter, forms by far the largest proportion of the weight and bulk of all vegetable and animal structures, composing generally from ninety to ninety-eight per cent. of their weight. Although the elements of organic matter form so large a proportion of all living bodies, yet they are not more essential to their existence than the inorganic or mineral portion.

The elements or constituent parts of organic matter are Carbon, Oxygen, Hydrogen, and Nitrogen, which, by their combinations with each other, form by far the largest part of the weight of all living bodies. Some of these elements, moreover, constitute the water which is found in the earth, the matter of the atmosphere which we breathe, and also in combination with mineral matter a very large proportion of the solid parts of the earth. Bodies existing so abundantly, so widely disseminated throughout the universe, are most important subjects for consideration and for attentive study. They are things which must be known, before successful agriculture can be practiced.

ORGANIC ELEMENTS.

Carbon and Carbonic Acid.—Of all the constituents of vegetable life, carbon is the most abundant. In its pure state it exists as a solid, differing in this respect from the other three, which naturally exist in an aeriform or gaseous state. It is the essential principle of the different varieties of charcoal. It is the chief constituent of all of those immense beds of bituminous and anthracite coal found in various parts of the earth. It is abundantly formed by burning wood, with but slight access of air, and can also be produced in a very pure form from sugar, turpentine, starch

and vinegar. The mineral called graphite or blacklead, is almost pure carbon, and the diamond is but perfectly pure and crystallized carbon. When united in certain proportions to oxygen, it then loses its solid, assumes the gaseous form, and performs a most important part in the process of vegetation. The compound thus formed is called *Carbonic acid*, it extinguishes burning bodies, and even in moderate proportion is fatal to *animal* life. Where combustion does not take place from the presence of carbonic acid, animal life cannot exist. It is the presence of this gas which causes the impurity of air in wells, and hence the custom of letting down a lighted candle before persons will venture to descend. If the candle goes out the air is certainly impure, and persons cannot encounter it with safety; and even when it exists in quantities not sufficient to put out the candle, yet enough may be present to produce serious and even fatal effects to those who encounter it. The injurious effects of this gas in wells can be obviated by pouring into them a plentiful supply of quick-lime, in water.

Although when breathed it proves so noxious, yet when taken into the system by other means, its effects are quite agreeable.

It is this which gives to the different artificial mineral waters their pungency, and to ale, porter and some kinds of wine, their pleasant flavor, which being lost by exposure to the air, renders them stale, tasteless and flat. Water absorbs it readily, and thereby acquires the ability of dissolving the mineral or inorganic constituents of soils; a most important property as we shall hereafter see.

It is always exhaled from the lungs of animals during respiration, and is formed by the burning of wood and coal; it is emitted from volcanoes, and is also a constant product of the decay of vegetable and animal matter, and therefore always exists in the atmosphere.

Since its sources are so constant and so abundant, the inquiry naturally presents itself, how is it that it does not accumulate in sufficient quantities to render the air unfit for the purpose of breathing. Here the science of Chemistry unfolds at once the Beneficence and Wisdom of the Creator in a most striking and wonderful manner. This wisdom and goodness is moreover manifested by means so perfect, and withal so simple as to call forth our highest admiration of, and our greatest adoration and gratitude to Him who employs them for our good.

"Whenever it is vouchsafed to the feeble senses of man to cast a glance into the depths of creation, he is compelled to acknowledge the greatness and wisdom of the Creator of the world. The greatest miracle which he is capable of comprehending, is that of the infinite simplicity of the means, by the co-operation of which order is preserved in the universe, as well as in organism, and the life and continued existence of organized beings secured."

The causes which I have enumerated would, if not counteracted,

soon render the earth unfit for animal life; but that which animals throw off as unfit any longer for their use, is that without which vegetable life could not exist. That which is poison to the one is food to the other. All vegetables absorb through their leaves this Carbonic Acid, (to animals deadly poison,) and separate the carbon so as with it to build up their structure; while they exhale the other constituent, oxygen, to purify the air. There is thus ever kept up a healthy balance in the atmosphere; and a constant and necessary relation exists between vegetable and animal life. Where the one exists in the greatest abundance, the other will also ever be found in like ratio, and animals depend for their food on vegetable production no more than vegetables on animals for the materials for their structure. Every tree, plant and shrub that grows purifies the atmosphere, and furnishes air for the use of man and the inferior animals; every thing that breathes the air—from man, the lord of the creation, to the veriest reptile—is a purveyor of food for vegetable subsistence.

Wherever, therefore, animals abound, carbonic acid is largely formed, but this carbonic acid, in giving its carbon to vegetables, gives also its oxygen to purify the air, and furnishes the means of breathing to men and animals. Decomposition of animals, and the decay of vegetables also, afford both carbonic acid and ammonia, the very materials for the growth of a new series of life. The death of one generation thus becomes the source of life to another, and each living generation is the phœnix arising from the ashes of that which preceded it, a life whose very existence depends upon previous death.

This is a type of what revelation teaches, that we shall not "surely die;" but that death is but a means to and a necessary precursor of a glorious resurrection. There is taught, too, by this simple yet beautiful and perfect process, the mutual dependence which exists, not for pleasure only, but for life itself, between all the systems of animated nature—that nothing is in vain.

Each humble plant that grows may be nourished by the breath of the greatest of mankind, and in its turn purify the air for the life of a hero. The frailest flower, though, perchance, "born to blush unseen," does not "*waste* its fragrance on the desert air." The perfume of flowers is a compound of carbonic acid and ammonia, and may be taken up by corn, wheat, or any other plant used as food by man.

There is ever going on a transmutation from living to dead matter, and these are ever assuming new and variable forms: the truth can easily be believed by the chemist that

"Cæsar dead and turn'd to clay,
May stop a hole to keep the wind away,"

and the fulfilment of the poetical prophecy:—

> "From her unpolluted dust,
> Shall violets spring,"

can readily be admitted, without poetical license.

The mode in which the various changes incident to vegetation are effected deserves a passing notice. In the process of germination, the sprouting of the seed, oxygen is absorbed, heat is developed, and probably acetic acid is formed, whose use is to extract from the soil bases useful for the further progress of the plants. The substance of the seed (starch and albumen) becomes soluble, and undergoes certain changes by which the woody fibre required for the stem and leaves is produced. The plant now must absorb from the air and soil, matter necessary for its growth.

By means of its roots, the necessary mineral matter is taken up, and also ammonia and some portions of its carbonic acid. By far the greater portion of the latter is, however, absorbed by numerous pores on the bottom of the leaf, and under the influence of light, carbon necessary for its woody fibre, gum, &c., is separated and retained; whilst oxygen, fit for the respiration of animals, is thrown out by pores on the top of the leaf. During daylight, plants are continually absorbing carbonic acid and giving out oxygen; in the night the contrary, to some extent, prevails; they then throw out carbonic acid. This explains partially the fact of the greater and more rapid growth of vegetable life during the summer season, when the days—the period of light in which the plants assimilate carbon and build up their structure—are much longer than in other seasons of the year.

Oxygen.—Another of the elementary constituents of organic matter is oxygen, and one of the most generally diffused in nature; though, contrary to what some have said, it performs no more important part than any of the other elements.

All are necessary; each performs the special part assigned to it; they are all links in the great chain of matter. It forms a large part of the atmosphere which surrounds the earth, about eight-ninths of all the water in existence, besides forming a very large proportion of rocks, minerals and soils. In water, it is in chemical union with hydrogen, and in the air it is only mechanically mixed, not chemically combined with nitrogen, both elements of organic matter hereafter to be described; but in soils and rocks it is combined with various bodies, affecting their properties in a very great degree. In its pure state it is invisible, colorless, tasteless, and without smell. It has a very strong affinity for almost all bodies. The *act* of combining with oxygen is called *oxydation;* and the compounds thus formed are called either Acids or Oxyds. The former of these possesses the general properties of acids; the latter of bases,

which, by uniting with the former, produce salts;* thus sulphur and oxygen in certain proportions form sulphuric acid or oil of vitriol. Calcium and oxygen in certain proportions form lime, a base which, when united to the sulphuric acid, produces a salt (sulphate of lime or gypsum.) The phenomena attending oxydation are very variable. Ordinary combustion is only oxydation taking place in a rapid manner; then again it takes place slowly, without any manifest development of effects, as when iron, zinc, or copper rusts. The burning of wood and the rusting of iron are both examples of oxydation; in the one case occurring more rapidly than in the other; and in each oxygen is obtained from the air. Another instance of slow oxydation is the gradual decay, or slow combustion, (Eremacausis, as it has been termed by Baron Liebig,) of organic matter when exposed to the air. By it all organized bodies are resolved into forms capable of being used as food for plants It is this gas which when breathed supports animal life, and almost all changes in animate or inanimate nature take place in consequence of its increase or diminution.

Hydrogen.—This is also one of the four organic elements. Like oxygen, it is very extensively diffused throughout all nature; like it, it is a gas invisible, tasteless and inodorous. It is the lightest body in nature, and hence used for filling balloons. It is never found isolated, but always in union with some other body. With oxygen it forms water, and with carbon the gas so generally used for light. It is very combustible, and when burned by means of the hydro-oxygen blowpipe, (an invention of the celebrated Dr. Hare, of Philadelphia,) produces the most intense heat yet known.

Nitrogen—Like hydrogen and oxygen, when combined, always exists in the gaseous state, and like them is tasteless, colorless and without smell. It forms about four-fifths of the atmosphere, a small proportion of vegetable, and a large share of animal matter. It has in its pure state no very sensible and direct properties, and is better known by those which are negative. It does not support combustion, but extinguishes all burning bodies that are surrounded by it alone, and no animal can live in it when pure, though it has no deleterious properties; combustible matter refuses to burn, and the animal dies because deprived of oxygen, or vital air. It serves as a diluent to moderate the action of the oxygen in the air which we breathe, for no animal can live but a short time in this latter gas; and if nitrogen was not present in the air, in a short time not only would trees and forests, but also iron and all other metals, be burned in one general conflagration. When combined with hydrogen, this substance forms ammonia, so necessary to the formation of vegetable and animal life, and that which constitutes the chief valuable constituent in Peruvian guano.

* Hydrogen is also essential to give sulphur acid properties

This substance, a product of the decomposition of organic matter, always exists in small quantities in the air, whence it is brought down by dew, rain and snow to the earth, where it is retained for the use of the plant. Although nitrogen exists so abundantly in the air, and forms so large a portion of plants, yet they cannot use it in its pure form; it must be supplied to them in the form of ammonia, or of nitric acid, as some say. Their leaves imbibe and exhale, but use it not. The experiments to support the contrary idea are inconclusive, as all their results can be explained without coming to the conclusion that nitrogen, as such, is supplied directly to plants from the air.

I have now given the most marked properties of the four elementary organic substances which form the air we breathe, the waters of the earth, a large part of the earth itself, and of the animal and vegetable tribes which inhabit it. The names and properties may not be familiar to some; very many may be entirely ignorant of them; but what can be more appropriate subjects for study and investigation, than the air which supports our lives from its first moments, the water which is to us daily food, or the composition of that food, which by the curse of labor we are obliged to earn—a curse, however, changed by mercy into a blessing, when the intellect is used to lighten the toil of the body? Is a knowledge of these substances useless? then the knowledge of those things nearest to us, and with which we hold constant relation, is useless; and if these are, those which are more remote must of consequence be more so, and all knowledge is vain; and if knowledge be nothing, then men are on a level with brutes—they are below them.

The most noted properties of these substances can be easily understood, and as easily learned as the multiplication table, and will enable the tiller of the ground to understand many facts of great use to him which are now incomprehensible, and give him, as the fruits of labor, pleasure as well as profit.

The substances which I have mentioned above, namely, carbon, oxygen, hydrogen and nitrogen, are combined with each other, and form many substances, of which it is not my province here to speak. I will mention some whose constitution it is proper to know.

Carbon and oxygen form carbonic acid, whose uses and properties I have spoken of above. Hydrogen and oxygen form water, which serves either as such, or by its elements, to produce a large part of the mass of vegetable matter; it moreover is the vehicle for the transportation of food to the plant, and causes matter, by dissolving it, to assume a form, giving to it the properties of food.

Though the above substances are of such vast importance in vegetable life, and form nearly all of the woody fibre, leaves, stem,

juices, gum, sugar, starch, acid, gluten, albumen, (the last two being the nutritive principle of wheat, corn, &c.) yet they are of no more use than certain other substances, which are of equal necessity to the animal, and are always present in productive soils, and in a form, state, or condition capable of being taken up by the plant. These essential elements are

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INORGANIC OR MINERAL MATTERS.

Silica, Silicious Earth, or Sand—Which is the oyxd of silicon, exists abundantly in all soils. Though having none of the sensible properties of an acid, it nevertheless belongs to this class of bodies, and combines with bases to form salts. It very rarely exists in a pure form in the earth, being almost always in union with some other substance, and forming a class of bodies called *silicates*. With alumina and peroxyd of iron, it forms our red and yellow clays; it most generally is associated with lime, magnesia, potash, or soda. The "grains of sand" in soils, are frequentlycomposed of pure sand (silicic acid) in combination with some of the above substances. In pure water, these combinations are quite insoluble; but water charged with carbonic acid dissolves them in a sensible degree. When first set free from its combinations, water dissolves it very readily.

Besides its determining, to a great extent, the mechanical properties of soils, and when in a very fine state of division, acting as a substitute for iron and clay in their absorbent capacity; it has a direct and independent use, that of forming the stalk and stem of plants, and the husk or outward envelope of the grain. In combination with potash, soda, lime and magnesia, but more particularly with potash, it gives hardness and firmness to the stalk of grasses, Indian corn, wheat, rye, oats, &c. It gives strength to the stalk to support the weight of the blades and ear; forms channels for the circulation of the sap, and for the transmission from the root, of whatever nutriment the other parts of the plant may require. Without the presence of this substance, and that too in a suitable state to be taken up by the roots, whatever quantity of the other constituents of plants might be present in the soil, vegetation could not arrive at any perfection. If the materials for the grain or ear existed, still there would be no stalk to support them.

The soils which, in common parlance, are called "sandy soils," frequently contain no more sand than those which are called "white oak soils, or pipe clay soil."

The difference in their texture is due to the size of the individual grains of sand, and not to the quantity which actually exists. Other things being equal, the finer the grains of sand the better

the soil. As the growing crop can only use such materials as are already in, or can be reduced to a soluble state, whatever can conduce to the state of solution, will benefit them. The finer the grains of sand, the more easily they are acted on by atmospheric agency, and the more speedily will they yield whatever substances they may *contain*. But there is another, and a very great difference in the value of coarse and fine sand. A large part of the food of plants is derived from the atmosphere. This food must be absorbed wholly by the soil, in the early growth of the plant; and if the soil has not the power of absorption, the plant will pine, languish and die, unless it be supported by applied manures. Sand, in a very fine state of division, has powerful absorbent qualities, it absorbs and retains atmospheric food for plants, and to a very great extent, supplies the place of alumina (clay), the peroxyd of iron, and vegetable matter, which are famous for this property.

Iron.—Another constituent of soils is *iron*.

It always is present, though not in the form of metallic iron, but in the state or condition of an oxyd of iron. When metallic iron is exposed to air and moisture, it becomes rough, and covered with reddish or brown scales. This is what is called, in common language, *rust of iron*, the process is called *rusting*. In Chemical language, it is called the *oxydation* of iron, and the product an *oxyd of iron*. There are three oxyds of Iron; when in soils, it is generally in the condition of peroxyd, or its highest degree of oxydation, and gives a reddish or brown color to them. It is this which gives our red and yellow clay soils their peculiar color, and frequently also tinges sand—which, thus colored, is called Ferruginous sand. It has several important uses in the soil.

First.—It is one of the necessary constituents of the human body, being always found in the blood of healthy persons. From the impossibility of its existence in the air, we know that the body must be supplied with it from the food which it consumes; but the plants used for food, can no more obtain it from the *air*, than animals can, hence they must obtain it from the soil, and it is therefore a necessary constituent of soils.

Not only is it itself food for plants, but it is a gatherer of food for them from the atmosphere.

Baron Liebig, one of the ablest writers on Agricultural Chemistry, of this or any other day, though overlooking the first use of iron in a soil, so clearly and satisfactorily explains the second, that I cannot do better than use his own words:

* "Peroxyd of iron and alumina," says this able and eloquent writer, "are dintinguished from all other metallic oxyds,) i. e. rusts of metals,) by their power of forming solid compounds with

* Chemistry, in its Application to Agriculture and Physiology. (Edited by Lyon Playfair and Dr. Gregory; 4th London Edition.

ammonia. The precipitates obtained by the addition of ammonia to salts of alumina or iron, are true salts in which the ammonia is contained as a base. Minerals, containing alumina or oxyds of iron, also possess, in an eminent degree, the remarkable property of attracting ammonia from the atmosphere and retaining it * * * * Soils, therefore, containing the oxyds of iron and burned clay, must absorb ammonia, an action which is favored by their porous condition; they further prevent, by their chemical properties, the escape of the ammonia once absorbed. Such soils act-indeed, precisely as a mineral acid would do, if extensively spread over their surface.

"The ammonia absorbed by the clay of ferruginous oxyds, is separated by every shower of rain, and conveyed in solution to the soil."

Our red and yellow clays need not burning, the iron in them being already in a state of peroxyd, heat would not benefit them. It is only in white or dark clays, where the iron is in the state of protoxyd, that heat would be of any use if applied.

The peroxyd of iron in a soil, also absorbs and retains moisture, and whatever else of the food of plants which exists in the air.

Third.—It gives firmness and compactness to the soil, and better fits it for those plants which flourish best in compact soils.

Fourth.—It gives color to soils, which makes them absorb heat better, and in this way it gives crops a quick, early growth.

Alumina.—Alumina, or pure clay, is another of the constituents of all soils. It, like iron, is the oxyd or rust of a metal called aluminum which never exists naturally in its pure state. "The different kinds of clay of which pipes, porcelain and earthenware are made, consist of hydrate of alumina, in a greater or less degree of purity." It has not the same important action as iron in the human economy, but its uses in the soil are very nearly the same, giving it tenacity and firmness, absorbing, like it, moisture and food from the atmosphere, forming "true salts" with ammonia, and having, like it, the properties of an acid or an alkali; of an acid, by uniting with alkaline bases such as potassa, lime and baryta; and of an alkali, by forming salts, with acids. Our red and yellow clays are by no means pure alumina, but silicates of alumina and the peroxyd of iron, united with lime, magnesia, and sometimes with potash, and very rarely with soda—that is, pure sand chemically united to these substances.

Lime.—The great use of this substance as a manure, and the frequent benefits that result from its application, make almost superfluous the bringing forward of any proofs of its necessity in a soil. Lime, like alumina, is the oxyd or rust of a metal, never existing naturally in its pure state. The metal of lime is called

Calcium. Lime exists in a soil sometimes as carbonate, that is, air-slacked lime, but most generally as silicate, that is chemically united to silicic acid, or sand. In the human body, in union with phosphoric acid, it forms a very large part of the bones. It exists in combination with different acids, in the root, stalk, blade, and grain of all plants.

Besides the necessity of its presence to form the structure of plants, it performs many other important functions in a soil. It promotes the decomposition of vegetable matter, and thus causes it to yield the different mineral substances which it contains, as means for the production of another growth. It improves the mechanical texture of the land; which is but one of its smallest uses. It powerfully aids the disintegration of the minerals (grains of sand) on a soil which contain many of the necessary elements of plants, and which, without the *fluxing* or *fusing* power of lime, would not yield them. This is one of its greatest and most important uses, and we cannot yet say, whether or not, lime, when applied to a soil, does not act more beneficially in this way than in any other.

Magnesia.—Magnesia is the oxyd or rust of a metal called magnesium, which never exists naturally in a pure state. It is one of the necessary constituents of soil, being found in the bones of animals, and in the roots, stalks, leaves, and grain of plants. It has, in many respects, the same action as lime, and to a certain extent can be substituted for it. The quantity of it varies in different soils. In some I have found as much as two per cent., equal to about six hundred bushels to the acre, to the depth of twelve inches, and in others but a mere trace. The facts to show what the best quantity is in a soil, are very meagre. As far as my knowledge extends, I believe that where it exists in a less quantity than two-tenths of one per cent., in a soil, magnesian lime is the best application for that soil. There were no experiments on the subject, and no means taken, any where, so far as I know, before those in Maryland, to lay down any foundation for experiment that will be worth any thing when made. My own knowledge, as to the action of it, is derived from gentlemen who have used both magnesian, oyster shell and pure stone lime on their lands, and analyses of the soils which I subsequently made, have led me to the above opinion, and are the only data yet given to the agricultural community on this subject. [See article—Lime, Manures.]

Potash.—Potash, the oxyd or rust of a metal called potassium, is another of the necessary constituents of soil. In union with silicic acid, it gives strength and firmness to the stalk, and to the husks or envelope of the grain.

The proportions in which I have found it to exist in soils are very variable, from a mere trace in some, to as much as (1.20) one

and two-tenths of one per cent. in others. But a very small quantity is absolutely necessary.

SODA.—Soda, the oxyd or rust of a metal called sodium, is another of the necessary constitutents of a fertile soil. It has nearly the same uses as potash, and may be substituted for it to a certain extent. It exists in various proportions in soil, but a very small quantity seems to be all that is necessary.

On salt water, land produces wheat with bright, strong straw—whilst land remote from it, with an equal quantity of inorganic matter, will not do this, because it is not supplied with soda from the atmosphere.

PHOSPHORIC ACID, is also one of the necessary constituents of a fertile soil. With lime and magnesia it forms about fifty per cent. of the bones of animals. Its elements are also found in the blood and brain, and in combination with different bases; it forms a very large proportion of all grains that are used for food. It exists in the soil, in combination with lime, magnesia, iron and alumina. With those substances, and others of this class, it forms salts, which are called phosphates. Unless there be this substance present in a soil, in sufficient abundance, and in proper *form* for use, no matter how rank or strong the crop of straw may be, there will be no corresponding yield of grain. Hence, in soils famous for large crops of straw, with a small quantity of grain, the farmer may increase it by the application of manures containing this substance, which are principally Bone Dust, Super-phosphate of Lime and Mexican Guano.

SULPHURIC ACID.—Sulphuric acid (commonly called Oil of Vitriol,) is also a necessary constituent of fertile soils. It most generally exists in combination with lime, forming with two equivalents of water, that which is generally known as gypsum. Its elements exist in all plants, and in the blood of all animals.

The quantity necessary to constitute a fertile soil, is very small. This has been shown by numerous practical experiments, as well as by many analyses.

Besides the soil, the air undoubtedly supplies the plants some portion of the two substances named above, or rather supplies the elements from which they are formed.

All animal and vegetable bodies, by their putrefaction, give rise to volatile compounds, containing sulphur and phosphorus, and under conditions which we know to exist, these compounds are changed into phosphoric and sulphuric acid, which, with bases, will form phosphates and sulphates. Although these two substances have not, as yet, been *detected* in atmospheric air, yet we know that they must exist there, and will be brought down by dew, rain, and snow, to the surface of the earth.

2

Chlorine.—Chlorine is another of the necessary constituents of a fertile soil. In its pure state, it "is a yellowish, green colored gas, which has an astringent taste, and a disagreeable odor." When breathed, it excites violent spasm of some of the upper parts of the wind-pipe, and has a very irritant effect on the organs of respiration, even when very much diluted with air. In the soil it is almost always united to soda, and *very* rarely to lime, magnesia or potash. United to any of the bases, it loses its poisonous properties. With soda it forms the different kinds of common table salt. It is believed to add to the weight of the grain.

The above compose all of the substances necessary to constitute a fertile soil. In some soils, manganese is found, which is the oxyd or rust of a metal called manganesium. This, though occasionally found in fertile soils, and in the ashes of plants growing on them, yet is not essential, since its presence does not increase, nor its absence decrease the productiveness of a soil.

The air, in common with the vegetable matter in a soil, furnishes to plants, carbonic acid, out of which they form woody fibre, and all substances in them which contain charcoal.

Besides this, it in common with many manures, affords ammonia, a substance which supplies a great share of the nutritious parts of plants, and constitutes, by its elements, a large part of the mass of the bodies of the vegetable and animal creation.

Water is supplied, in this country at least, wholly from the atmosphere, in the form of dew or rain.

To recapitulate, then, we have as food for plants furnished by the soil alone:—

Silica or sand,	Magnesia,
Alumina or clay,	Potash,
Iron,	Soda,
Lime,	Chlorine.

We have furnished in a great measure by the soil, but partly also by the air:

The elements of Phosphoric acid—

The elements of Sulphuric acid.

In localities adjacent to the ocean, bay, or indeed any salt water, there is always present in the air, both soda and chlorine in the form of common salt.

We have furnished in a great measure by the air, but partly also by the soil:—

Carbonic acid containing carbon—

Ammonia containing nitrogen, and

Water.

These contain all of the elements necessary to the perfection of vegetable and animal life. Those of them which are not present in the soil in sufficient quantities, and which cannot be derived

from the atmosphere, must be supplied artificially by what are called, and are then manures.

Although the ten last named elements form but a very small per centage of living bodies, yet they are absolutely essential in their existence; for without phosphate of lime and magnesia, which is a compound of phosphorus, calcium and oxygen, neither the bones of animals nor the seeds of grass nor of grains would be formed. Without sulphur no nutritive food capable of yielding blood or brain matter could be produced. Without silicate of potash and soda no stem of wheat, no blade of grass nor stalk of corn could exist.

It may be interesting here to state the various parts and secretions of the body in which the different mineral constituents occur.

Phosphate of Lime occurs most largely of all the mineral constituents of the human body. It is found in the bones, blood, milk, urine, fæces, &c.

Carbonate of Lime forms the principal part of the skeleton in the invertebrata, (animals who have no spine,) such as crabs, oysters, &c. It also occurs in the bones of higher animals and man, in egg shells and the urine of those animals which feed on grass.

Phosphate of Magnesia is very frequently associated with phosphate of lime. It occurs in bone, blood, milk, egg shells, urine, &c.

Fluoride of Calcium sometimes occurs in very small quantity in bones. It is abundant in fossil bones.

Hydrochloric Acid exists in the digestive fluid of man and all animals that give milk to their young.

Chloride of Sodium (common salt) exists in the blood, gastric juice, urine, bone, cartilage, (gristle,) &c.

Carbonate of Soda is found in various animal substances, especially in the urine of animals that feed on grass.

Phosphate of Soda occurs in the lymph, bile, chyle, milk and urine.

Chloride of Calcium is found in the gastric juice and saliva.

Chloride of Iron is found in the gastric juice.

Alkaline Sulphates are found in blood, sweat, urine, &c.

Iron is found in considerable quantities in the coloring matter of blood, in chyle, black pigment of the eye, hair, &c.

Chloride of Potassium is found in almost all of the animal fluids.

Silica has been found in the enamel of teeth, in bone, hair and saliva.*

The above compounds contain all of the substances which I have before named as necessary to constitute a fertile soil, viz:

* Simon's Chemistry of Man

silica, iron, alumina, lime, magnesia, potash, soda; also phosphoric and sulphuric acids and chlorine: they are necessary in a soil because they are necessary to animals who have to derive their food from the soil.

The most abundant supply of all the four organic elements first mentioned, which exist in the air, could not produce the smallest plant or the veriest insect that crawls, unless it was in union with the other bodies last named, which are derived from the soil. The soil thus furnishes a material class of bodies which cannot exist in the air, necessary to the animal and necessary to the plant, and with which we must supply the soil, if they be absent, before vegetable life can be produced. In my first report I gave a table showing that all of the mineral constituents named above were necessary; that the absence or deficiency of one could not be compensated for by an excess of the others. Thus—no amount of lime would compensate for the absence of magnesia; no abundance of chlorine be a substitute for sulphuric acid; no quantity of sulphuric acid could counterbalance a deficiency of phosphoric acid or phosphates. Let those who deny this doctrine and say that all these constituents are not necessary, show a single grain of wheat, a single blade of grass, or any soil capable of producing either, which does not contain them. But not only this, a part of the substances existing in the air are first taken in by the soil and then furnished to the plant—the soil being a medium, a kind of stomach for the proper digestion of the food obtained from the air, so that it may be used by the plant. This digestive power, or ability to produce nutritive matter, such as ammonia, from crude substances, (hydrogen and nitrogen,) depends partly on texture, partly on chemical constitution. Ammonia, as I have before said, is a compound of hydrogen and nitrogen, which is supplied abundantly to crops by the air, provided the soil has the capacity of absorbing it, or of forming it from its elements; but many soils have not this power, and it then must be supplied from other sources, such as Peruvian guano, stable manure, &c. So, then, the capacity of production in soils depends upon the presence in them of the last ten substances named, and upon their ability to form ammonia from its elements, to absorb and retain it when already formed, and to absorb and retain watery vapor—products of the four first named. This power of absorption is due partly to their chemical, partly to their mechanical nature. We must look to their chemical constitution to determine the presence, absence, or deficiency of those first named, to the chemical constituents and to their mechanical texture, to the fineness of the several particles which make up the mass of soils, to determine their absorbent quality.

The organic elements form, by different modes of combination,

a very large number of substances peculiar to different plants, which substances make a difference between different classes. Thus we have gum, sugar, starch, a great number of oils, such as peppermint, turpentine, &c., a great variety of perfumes, and an almost endless variety of substances used in medicine, such as quinine, strychnine, &c., all composed of organic elements. A great many substances have been discovered amongst organic bodies composed of the same elements, and yet exhibiting physical and chemical properties essentially distinct from each other. A great class of bodies known as the volatile oils, oil of turpentine, essence of lemons, oil of balsam of copaiva, oil of rosemary, oil of juniper, and many others, differing widely from each other in their odor, in their medicinal effects, in their boiling point, contain the same elements—carbon and hydrogen—in the same proportion. No one of them contains more of either element than the others do. Nature, in her perfect laboratory, furnishing all these by skillful arrangement and mode of union; now making food to support life; now a deadly poison to destroy it; now a sweet perfume; now a most fetid odor; now a brilliant dye. We have the same elements partially under our control, and though we cannot vie with her in formative skill, yet we can, by calling the intellect to aid the labor of the hands, make the earth to yield its fruits abundantly, secure a sustenance for ourselves and a heritage for our posterity.

THE ORIGIN AND MODE OF FORMATION OF THE SOIL.

The soil is that portion of the earth which forms its outer crust, and is indispensable to the vegetable world, as well to give it mechanical support as to furnish it materials for growth and nourishment. It consists of the remnants or small particles of different rocks, (inorganic matter,) intermingled with the remains of animals and plants, (organic matter.) A brief survey of the different kinds of rocks; the multifarious mechanical and chemical influences to which they are exposed, the effects of which are destructive to their coherence—will show the manner of the formation of the soil, and disclose the general nature of its constituent parts.

The various kinds of rocks which form the solid part of our globe, are absolutely distinct from each other by their origin and character, and naturally divide themselves into two principal classes, in various forms, viz: in Igneous forms, such as originate from the effects of fire, and are found in large bodies, without the least regularity in the arrangement of their particles; and in Neptunic

forms, viz: such as are gradually precipitated, from their solution in water, and lie in more or less parallel layers.

This variance in the origin and general geological character of the two grand formations, must necessarily be accompanied by a variance in their chemical nature; and we really find a state of things to exist equally as distinct as the mode by which they were produced.

Whilst the various minerals of which the volcanic or igneous formations are composed, contain silica as their principal ingredient, either in a free state, or united to alumina, (clay,) and the alkalies, (potash and soda,) or lime, (oxyd of calcium,) and the protoxyd of iron—the Neptunic (aqueous) formations, on the contrary, show lime or some other base, as their principal constituent, united to carbonic acid, muriatic, or sulphuric acid. The former (the igneous class,) is characterized by a predominating acid, viz: the silicic acid, and comprehends the numerous varieties of minerals known by the name of silicates; the latter, on the contrary, are characterized by the existence of strong bases, viz: lime, magnesia, potash, soda, &c., which united to weaker or stronger acids form the large class of pure and alkaline earths. These two classes do not differ in regard to their geological or agricultural importance; that is, in the share which they take in the formation of the crust of the earth. We find that granite, gneiss, mica-slate, syenite, basalt, and many others, representing the class of silicates, in equal extent with pure alkaline and saline earths, amongst which, lime-stone, dolomite, anhydrite, (gypsum without water,) gypsum and common salt, are of most importance. The share, therefore, which both take in the formation of the soil, is of equal importance.

An investigation into the causes which produce the gradual destruction of these masses of rocks, will show that they are either of a mechanical or chemical nature; both of these, co-operating, produce the effects which we see around us in the formation of the soil. We have to examine these causes in the influence of water and air, for it is water and air, these two great universal agents, that possess all the power necessary to rend asunder the firmest masses of rocks and convey their fragments to distant regions, in which they appear as a more or less fertile soil.

The degradation of rocks, is the consequence of chemical action; of the cotemporaneous influence of carbonic acid, of oxygen in the atmospheric air, and of water upon their constituents. One of the most characteristic elements of the Silicates, is Silica; existing in them either in a free state, as quartz, or it is united to potash, &c. in mica, feld-spar, and other minerals; in the former state it is insoluble, in the latter, when separated by means of acids or any other cause it is soluble. In this form silica acts as an acid; but its affinity for the bases is so slight that even carbonic (a very

weak) acid, is capable of driving it from its combinations. Granite, a silicate, composed of quartz, feld-spar and mica, contains both modifications of silica, as constituent parts of its composition. Its uncombined silica, (quartz,) is insoluble. Its combined silica in the feld-spar and mica, is soluble. The feld-spar may be considered, properly, a double silicate, composed of silicate of alumina, and silicate of potash. The same is true of mica, or isinglass, a mineral similar in composition to the feld-spar. We thus can explain the rationale of the decomposition of granite, if exposed to the influence of water and the atmosphere. The silicate of potash is decomposed by the carbonic acid of the air, and carbonate of potash and an acid silicate of potash formed, both being soluble in water. If these substances are washed out, quartz, pure sand, (the uncombined silicate,) and a white mass of kaolin, silicate of alumina, (clay,) in a pulverulent condition, remains.

The action of atmospheric oxygen manifests itself in another way in the decomposition of the silicates, many among which as hyperate, syenite, basalt, and others, contain in chemical combination the protoxide of iron, which very greedily attracts oxygen from the air, in order to procure for itself a higher degree of oxydation, as pure iron does when exposed to air and moisture. The immediate consequence of this change, is the formation of new combinations, which produce an alteration in the position of the atoms, the smallest parts of the minerals, so that their original solidity is diminished, and a continued crumbling into small pieces and in the course of time, complete disunion takes place. If the silicates contain, as is frequently the case, combinations of metals with sulphur, (sulphurets,) as iron pyrites, copper pyrites, &c., diffused in the finest particles through this mass, their decomposition much more readily takes place, inasmuch as these components have their ingredients transformed by the absorption of oxygen into their corresponding salts; iron pyrites becomes sulphate of iron, copper pyrites sulphate of copper, &c. The salts are very soluble in water, and will be gradually washed out by its influence.

The capacity, then, of the silicates for decomposition, depends on the quantity of the silicate of potash, and of such other substances as absorb oxygen, and have in this way a change of their chemical composition. We always find that the larger the quantity of these substances, the more quickly and thoroughly is the exposed rock decomposed.

The origin of the Neptunic rocks, already has shown us the influence which water and air have over their ingredients. They are all soluble, to a greater or less degree, either in pure water, or in water impregnated with carbonic acid.

The property inherent in water, to occupy a larger space when

frozen than when in the liquid state, is one of the chief mechanical causes in destroying the cohesion of rocks and stones. It is a well known fact that this increase of the bulk of water, when frozen, is able to overcome *any resistance, however great*, which may oppose it. Compared to it, gunpowder and steam sink into insignificance. In autumn, during rains, we find mountainous countries very moist; caverns and fissures, which exist in rocks are then filled with water, which gradually leaks through the smaller clefts, percolates through the pores, until finally, it pervades every part of the rock. With the first freeze the inclosed water is converted into ice, expands and bursts the rocks which oppose the expansion, which thus become converted into small fragments. In spring, when a thaw takes place, the rivers and streams which flow from the mountains are filled with water holding earthy particles in suspension, (the fragments of rocks broken by previous frosts,) which are borne down by the rivers to the various districts watered by them.

The mountain rivulets, nearly dried up in summer, become strong, and by their fall, rapid torrents in winter; forming thus a brisk and rapid communication between mountains and valleys. In a level country, rivers find a comparatively spacious bed; and when over-flowing their banks, deposit the material which they hold in suspension,—thus forming, according to the nature of the rocks through which their branches flow, a more or less rich soil.

The soil, the present subject of our consideration, is to be examined in a manner which, of course, must differ from the methods commonly applied to minerals, &c., as well in regard to a separation of the substantial from the unsubstantial, by which, most especially, time will be saved, as it must at the same time include an investigation into the nature of its composition in general and of the components in particular. On the condition and form in which those substances exist in the soil, depends entirely the mode of their participation in the development of plants, whether they partake directly or indirectly, as active, as reserved, or as passive components. An analysis which does not offer a full sight, into all these conditions, is nothing but a worthless work, from which neither practical nor theoretical conclusions can be drawn; and it is certainly not too much said when I pronounce the existence of the many analyses of soils, which are distributed through books or daily manufactured by Chemists, and which show every thing but that which is essential for the farmer to know, to be the reason of the discredit into which chemical agriculture is sunk in the minds of so many rational husbandmen. For it is important, besides the performance of a chemical analysis of soil, to take notice of its locality, physical properties, former improvements, and the condition in which the soil-constituents exist in it. It may be said that

two soils, which in their general character as well as in their productiveness, materially differ, can show exactly the same elementary composition ; the difference between them is only a necessary consequence of the different mode in which the various constituents in them are united to each other. Even if we look at the composition of "Grauwacke," a rock, which is composed of quartz and mica, we can hardly find out a difference between its elementary composition and that of a fertile soil.* A body of this kind would be very similar in composition to a loamy soil, which is capable of producing the fairest crops ; while the grauwacke, even if we would crush it into the finest powder, would not be able to support the life of our cultivated plants in a prosperous manner, until it became decomposed.

ON THE PHYSICAL PROPERTIES OF THE SOIL.

We perceive by the different analyses of soil, that the most considerable mass of the soil, is formed of only four substances, viz : Silica, Oxyd of Iron, Clay and Humus, and that all others, in comparison to the quantity of these, are present only as traces. This is true of all soils with the only exception of those which are characterized by a notable quantity of Carbonate of Lime and Magnesia which they contain, (calcareous soils.) The physical properties of soils consequently depend on the relative quantities of those four fundamental ingredients of which they are constituted, and are, therefore, as different as the numerous proportions may differ, in which these substances can be mixed ; or by the same relative proportion of them, as different as the various modes of combination may differ, in which these substances are united to each other. All these circumstances are at once considered by the farmer's practical eye and judgment whenever he gets a soil under examination, and they give him indeed a true and sure

* The composition of the Graüwacke is the following:

Sand and Silica - - - - -	72.2
Oxyd of Aluminum, (Clay,) - -	11.7
" " Iron - - - - -	10.4
" " Calcium, (Lime,) - -	1.0
" " Magnesium, (Magnesia,) -	2.3
" " Potassium, (Potash,) - -	1.0
" " Sodium, (Soda,) - -	
Phosphoric acid - - - - -	0.4
Traces of Chlorides - - -	1.0
" " Sulphates - -	
" " Organic Matter and Water -	
	100

measure as to the capacity and value of the soil in general, as already mentioned. That is, the exterior disposition of a soil is far more highly esteemed by him than the degree of its absolute capability of giving nourishment to plants, inasmuch as by purchasing a farm, it is less valuable for him to know how much of nourishing substances is at present in the soil, than to know whether a soil shows such a condition as to render it capable of producing fair crops by a proper treatment. He looks, therefore, most especially to its physical properties, and proves by manual examinations, as to the compressibility in the wet and dry state, as to the color, the depth of the soil, the quality of the sub-soil, the location, general climatic relations, &c., whether the earth is loose, easily falls to pieces by exposure to the air, possesses the proper degree of consistence, without giving too much resistance to agricultural implements; retains the absorbed moisture in the necessary degree, without becoming wet and cold, &c.

Although these examinations are indeed of quite a practical character, the Chemist still is enabled to aid the farmer in them. For the Chemist knows exactly the nature of the components of soils, and therefore the part which each single substance takes on the general character of them; he knows also the nature of the rocks, by the disintegration of which the soil was formed, and therefore the particular condition, the manner of combination, in which those components are present in soils. The investigations of the Chemist into this matter, assist if not in the judgment of the quality of soils, yet, in the judgment of means and ways, which ought to be taken for the improvement of a particular soil, I say they lead to results which can be expected with more confidence than those which are founded upon the experiment of the farmer alone. We shall see in the following that, in relation to an improvement of the soil in general, as to its texture, the Chemist may give an important judgment about it as well as the farmer; and in many cases a judgment which the farmer would never have reached by himself.

A general geological glance into the localities of those soils, which are in particular under our consideration, will lead us at once to some important conclusions. The soil of the north-east part of Maryland, (Carroll County, Harford County, Baltimore County, and a part of Frederick and Cecil,) is composed chiefly of the fragments of volcanic rocks, upon which the soil directly lies, intermixed with various quantities of alluvial matter. These volcanic rocks, as Granite, Syenite, Mica-Slate, and others, are silicates according to their chemical nature. We meet them in these localities almost every where, covered only by alluvial formations of small thickness. All those formations of aquatic origin, which were formed by precipitation from their solution or suspension in water, and which, in their regular occurrence, we find

lying above volcanic rocks, are absent here, inasmuch as this distinct locality did not favor their settlement.

There are in Maryland three totally different kinds of soil, viz: Firstly, soils formed by the disintegration of volcanic rocks. These soils, when they have gone through the process of washing, leave as a body the remnants of Granite, Syenite, Mica-Slate, with Garnets, &c., in a finer or coarser state of fraction.

Secondly, soils of mountainous regions, most especially with those of the great coal region of Cumberland, and therefore formed by the disintegration of gray Sandstone, red Sandstone, Limestone and Clay Slates. Their body consists, therefore, of the remnants of these rocks, which appear in them in various states of comminution. Thirdly and finally, we become acquainted with soils, which owe their deposition and depths to rivers and streams of mountainous regions, which, by their arrival in lower districts, have deposited again, in form of mould, fragments of the rocks of the country through which they flowed.

The body of these soils is composed of all those ingredients, which formerly were constituents of rocks, and which are now present as single substances, almost entirely separated from each other. When these soils have gone through a process of washing, nothing will therefore remain but sand, as it is in rivers: of more or less perfectly round, finer or coarser grain, Peroxide of Iron, Clay, Humus, Carbonate of Lime, &c.

After the foregoing remarks on the character of these soils in general, as is due to their origin and the geological relations of their locality *in particular*, let us now proceed to a contemplation of their *general* treatment for the purpose of cultivating and improving them in a proper and rational manner.

As to the soils under our first head; those which have been formed by the slow disintegration of volcanic rocks, upon which they directly lie; all of them are in general remarkable by their small thickness and little binding power. This circumstance is due to the large quantity of volcanic rocks present, which are mixed only with a small quantity of alluvial matter, the product of disintegration of the former. These rocks, in their *undecomposed* state, show as to their ratio as constituents of soil not the least difference with that of common coarse sand; whilst in their *decomposed* state, they are the source of an immense quantity of those substances, which not only serve as a nourishment for plants, but which also improve the soil materially in relation to its texture. A glance into the chemical composition of the components of these volcanic rocks, will show us at once in what manner a decomposition of them will improve the texture of the soil.

	Felspar.	Mica.		Hornblende.	Augit.
Silica, - - - -	65.72	47.50		45.69	50.11
Alumina, - - -	18.57	37.20		12.18	6.68
Peroxyd of Iron,	trace	3.20	Protoxyd	7.32	7.55
" Manganese,	trace	0.90	Protoxyd	0.22	
Lime, - - - -	0.34			13.83	18.66
Magnesia, - - -	0.10			18.79	15.72
Potash, - - - -	14.02	9.60			
Soda, - - - -	1.25				

All of the volcanic rocks, without exception, are composed of mixtures of various portions of the above-named minerals, which in their composition show substances of high importance to agriculture, but inasmuch as the single substances are united in them to each other, forming as a whole, a silicate of indifferent character, like sand, they can form in this condition nothing but a poor soil, which in no way can answer the demand which the plants require from it. These substances only require to be liberated, to exercise in full their influence on the quality of the soil; from a light and sandy soil of small depth, would then at once arise a soil containing a sufficient quantity of clay to become tenacious and binding, a sufficient quantity of Peroxyd of Iron to exercise an attractive influence on atmospheric ingredients, on heat, &c., and finally of alkalies and soluble silicic acid, which are direct nourishments for plants. We know that by the influence of air and water, all of these substances will be decomposed, the manner of which has been shown already and indeed, the quantity of sand, clay, oxyd of iron and lime on one side, and soluble substances on the other, which we find in these soils already in a liberated condition, indicates in what degree the disintegration of them has advanced during past ages. But as this process goes on very slowly, the agricultural question therefore arises, by what means this process of disintegration can be quickened; and here theory as well as practical experience gives us at once the remedies which are required.

We know by experience made on many localities, the geological character of which was similar to that of the soils under consideration, that the action of water-slaked lime on them, was always accompanied by a wonderful success in relation to their culture. This success is also well sustained by a theoretical contemplation of the properties of water-slaked lime, as far as they are brought into action. Water-slaked lime is an *hydrate* of the *oxyd of calcium* mixed with carbonate of lime, the proportion of which depends on the length of time during which the former compound was exposed to the air, and into which, finally, it will be totally transformed. The hydrate of the oxyd of calcium is remarkable for its great affinity to silicic acid, as it exists in silicates, viz: in its combination with alkalies, oxyd of aluminum, (clay) or iron; in consequence of

which, silicate of lime will be formed by the application of water-slaked lime to those soils which contain silicates, whilst the remaining ingredients of the decomposed rocks, as silicic acid, alkalies, oxyds of iron and aluminum, (clay,) become liberated and fit to improve the soil by their respective properties, either by their participation in the formation of the body of the soil, (clay, iron, &c.) or inasmuch as they are required as a direct nourishment for plants, (alkaline salts, silicic acid.) This chemical action of water-slaked lime takes place so much more readily, as the lime is abundantly soluble in water, and therefore capable of penetrating soils thoroughly in all directions.

Water-slaked lime should never be applied to a soil, unless the soil is perfectly dry or well drained, so that water cannot rest on it. If it is applied to a wet soil, it may in most cases occur that an action between lime and the sand in soil takes place, in consequence of which a solid compound is formed similar to hydraulic mortar, both in relation to its formation, and to its physical properties. The formation of this compound of course will prevent the beneficial influence of the lime which we expect; the texture of the soil will be injured, instead of being improved.

The quantity of water-slaked lime to be applied per acre, should be between 20 and 50 bushels, (according to the quantity of undecomposed rocks present,) and the application should be made in the fall on ploughed land, so that the lime may exercise its influence during the winter time.

The rational treatment of these soils is finally concluded by the application of a heavy dressing of common stable manure, or the turning in of green clover, as soon as the water-slaked lime has been totally converted into carbonate of lime. Stable manure, which will be converted into humus, prevents the too strongly and quickly dissolving and extracting power of the water on those substances in soil which are soluble in water, and which were formed previously by the action of the lime. The humus envelops these substances, transforms them to less soluble salts, and reserves by these means their surplus for a future time. Experience has taught us that heavy rain-showers by running off from a soil which contains a proper quantity of humus, take away only a very small quantity of soluble salts, which they extract from the soil. Humus, therefore, protects the nourishing power of a soil, without taking a direct part in it, as was formerly supposed to be the case.

In Frederick county partly, and in Washington county, we meet a soil which may generally be pronounced a stiff clayey soil. Its color is dark brown or reddish, and its particles are granules, united to each other by a clayey cement; showing the general appearance of an alluvial soil of great capacity and productiveness.

In relation to an improvement in the physical properties of these soils, the principal care must be directed to the restoration of their

communication with the atmospheric ingredients, or, in other words, manures ought to be applied which in part decrease the binding power of the clay, by which means the earth becomes looser and more porous.

This effect will be produced by the application of a marl, which contains more sand than clay, besides a proper quantity of carbonate of lime, or, in the absence of this, air-slaked lime, which has nearly the same influence, and it seems to me that the application of this substance is especially appropriated to this class of soils of which I presently speak. The carbonate of lime in the marl takes its place between the clay, humus and sand particles of the soil, and tempers by its presence the tenacity and binding power of the clay; in consequence of which the soil may easily crumble, and its impenetrability to water and the ingredients of the atmosphere may decrease; whilst the proportion of sand and clay in this kind of marl supports this effect. The analyses of these soils always show a deficiency of lime relative to the proportion of sand and alumina in them.

The soils of Alleghany county are those which are formed by fragments of clay slates, of gray sandstone, red sandstone, limestones, &c. They are loamy, rather calcareous soils, as we see by their analyses above given, and show, as a consequence of their composition, that they are, pervious to the influence of air, and permit the rain-water to penetrate them intimately, not to rest upon them, so that wet seasons will not do any harm here: a dry season is rather to be feared.

The defect in these kinds of soil, is especially their little depth and the want of uniformity of their particles, inasmuch as we find large fragments of rocks intermingled with fine and coarse ones, as the constituents of their body. In this matter, therefore, our point of view ought to be directed especially to the deepening of the soil, and to the restoration of its uniformity, both of which will be done by means of a decomposition of the rocks. We have previously seen that the decomposition of volcanic rocks was done by the action of water-slaked lime on them; here a chemical action, that of lime, was induced to a chemical compound (silicates), and the good result was the consequence of a chemical process. In this case, however, the *chief* compounds present are not *chemical* compounds. Those rocks above named, consist principally of a merely mechanical mixture of substances which we also find in soils, and their separation, of course, must therefore also be done by a mechanical process. The application of lime on these soils would also be inadmissible, for a second and third reason, inasmuch as lime is already in abundance present in them, and the whole action of the lime would restrict itself to the decomposition of the humus, the quantity of which is rather deficient. Lime would act on this soil as on many other soils, for

the first few years excellently, inasmuch as it decomposes clay and humus, by which process alkalies, &c., previously retained by them, will be liberated, and a greater activity in general will be produced; for the future, however, not at all satisfactory; inasmuch as the soil became exhausted, the humus decomposed, and therefore no substance, which preserves nourishment is present, without which a proper texture of a soil cannot be possible. The soil is in such cases over-limed. It is on this class of soils in England that arose the proverb, "lime enriches the fathers, but impoverishes the sons."

For these soils, in general, we have to apply stable manure, or in want of it, we have, from time to time, to turn under a lay of green clover. By means of this treatment we produce soon a considerable quantity of humus, which is now deficient, and give at the same time the means for the rise of a great mechanical force in the body of the soil, viz: by the carbonic acid gas which is constantly going off from the Humus and which favors the crumbling of these fragments of rocks, inasmuch as the Humus became intimately mixed with them.

Finally, as to the soils of the Eastern Shore and the southern counties of our State, it has already been stated that they are of alluvial origin and composed principally of fine river sand, which by means of washing, it is very easy to separate from the rest. On account of the fine grain of the sand, however, and of some clayey cement always accompanying it, the soil possesses cohesion and water-reserving power to remain fresh and plastic inside, whilst the outer crust has already become dry. Soils of this same kind, which are composed of coarse sand instead of fine sand, are much less fertile than the former; we do not, however, meet them very frequently in these localities. Those of red color (peroxyd of iron) are generally more productive than the gray. The principal object in improving the mechanical texture of these kinds of soil must be directed to the increasing of the quantity of clayey cement, besides a proper quantity of carbonate of lime, by which means the binding power of the earth is increased without doing any injury to its porosity. The application of a marl of more clayey than sandy or calcareous constitution, will perfectly answer in this case.

THE DIRECTLY NOURISHING PROPERTIES OF SOIL.

We have considered in the foregoing part the fundamental ingredients of soil and described the highly important influence which they have on vegetable life, inasmuch as the mechanical texture of the soil depends on their various proportions, as well as on the

condition in which they are present. A soil however, which would contain no other substances but pure sand, clay, peroxyd of iron, lime and humus, and even these in such a proportion as is considered the most proper, would be in spite of the highest culture entirely sterile. In the following section we shall become acquainted with a series of substances which are essential to vegetable life, inasmuch as they are required by plants as nourishment; and as they can be supplied by no other means than by the soil itself, they must be present in it whenever the soil exercises fertilizing properties. This series of substances includes all those in soils which by their chemical character belong to the class of salts, and which are more or less soluble in rain water, and by means of their solution therefore capable of entering into the organization of plants; the fundamental ingredients of soil show in every respect quite a different character, as already stated. These salts consist principally of the following: alkaline salts, (potash and soda,) earthy salts, (lime and magnesia,) phosphates, (salts of phosphoric acid,) sulphates, (salts of sulphuric acid,) chlorides, (salts of hydrochloric acid,) and silicates, (salts of silicic acid.)

Total sterility of a soil, as we supposed it in the foregoing, rarely exists in reality, inasmuch as the absolute absence of soluble substances, can only be in a field which would entirely consist of fine quartz sand; the presence of clay and humus, includes at the same time that of alkaline salts, some of which are always retained by them, so that a chemically pure clay and a chemically pure humus, never exist in soils. The former will never become totally decomposed, and the latter will always retain some of these substances as long as it is present itself, and not totally transformed into carbonic acid and water. It may happen that a soil, which consists of the fundamental ingredients and from which a series of crops were taken, does show only traces of those nourishing substances, or even none at all, when they are to be extracted by water; but this state does not indicate that of absolute sterility, but merely that of temporary sterility, inasmuch as it yet contains nourishing substances, which, however, are retained by clay and humus in such a form that water may not extract them. After several fallowing-seasons, by exposure to the air, which may be increased by mechanical loosening of the earth, by deepening of the soil, &c., the fertility of the soil may be restored, in consequence of the advanced disintegration of clay and humus, by which new quantities of soluble substances become liberated.

We have in the foregoing considered the important part which the fundamental ingredients of soil take in the development of plants, inasmuch as it depends on their relative proportion and on the condition in which they are present, as a soil is more or less fit to offer those supports which vegetable life requires. In the following I shall endeavor to explain, how the quantity of solu-

ble mineral substances which the soil contains, gives a measure of the directly nourishing capacity or fertility of a soil.

At the commencement of this century Theodore de Saussure already perceived the importancc of soluble inorganic or mineral substances in soils in relation to the vegetation of plants, inasmuch as he considered them as directly nourishing substances, without which vegetable life could not exist. Before this time the gravest philosophers entertained the opinion that mineral matter in plants were only accidental circumstances, or, that if they were necessary, the plant had the power of transforming one into another, or indeed of creating them. They believe that there was something in the force of the vital principle, which could change iron into lime, lime into sand, or sand into potash, to supply the wants of the plant. The mineral theory was, however, attacked by many authorities, but recently it was brought to perfect proof by Wiegmann and Polstorff. These gentlemen have proved by direct experiments that plants will die if they cannot obtain the necessary quantity of mineral substances from their surrounding soil. The results of observations made by the Prince of Salm-Hortsmar, in this matter are especially interesting, and may be given in the following summary: In a mixture containing all the various substances which are required by plants as nourishments, except silicic acid, plants of oats remained low, pale and dwarfish; without lime, they died after the second leaf; without potash and soda, they reached only a height of three inches; without magnesia, they remained weak and lying down; without phosphoric acid, very weak, but upright and of normal formation; without sulphuric acid yet weaker, upright and of normal formation, but without fruit; without iron, they remained very pale, weak and badly formed, and without manganese, they did not reach their full strength and showed but a few flowers. Soda could not represent potash in relation to the strength of the plants. Magnesia could not represent lime. If, however, all of the mineral substances which vegetable life requires were present in their proper proportion; and sufficient quantity, the plants of oats reached a complete and pretty luxurious development, even with an entire absence of humus or any vegetable substance in the experimental mixture.

As to the character of the solution in which those nourishing substances are absorbed by the plants, it has been stated by Boussingault, that annually by a good crop of one hectare* about 200 kilogrs.† of soluble mineral substances are taken away. But during the growth of these reaped plants, about six millions kilogrs. of water were evaporated from the surface of their leaves; a quantity which previously was taken from the soil before it could evaporate from the leaves, and which always contained some soluble mineral substances in solution, which were left behind in the plants.

*One Hectare is about 2½ acres. †One Kilogramme is equal to 2½ lbs.

Those 200 kilogrammes had been, therefore, dissolved in six millions kilogrs. of water, or, in other words, those soluble mineral substances enter into the roots of plants in a state of 1-30,000 of dilution in water; of course a very weak solution.

After these general foregoing remarks, I am now going to treat upon these nourishing mineral substances in particular, as to their origin, their importance for vegetable life, the extent to which they ought to be present, and by what substances of commerce they may be properly acquired. These substances may be represented under the following heads:

1. Alkaline Salts (Salts of Potash and Soda,) and Soluble Silicic Acid.

Origin.—Both of those substances which are on the head of this paragraph, owe their origin to volcanic rocks, which are composed of them as I have stated already in many places before.—By the disintegration of these rocks, they are partly liberated and partly retained, according to the advancement of this chemical process. Those rocks, among the volcanic or silicious, which are before all others, rich in alkalies, are, at the same time, also those which contain considerable quantities of clay, which, in combination with quartz, peroxyd of iron, &c., forms the last and remaining product of the disintegration, inasmuch as they cannot be transformed into other compounds. Wherever we find clay, whether in mountainous regions, or as a component of soils, it derives its origin from the disintegration of volcanic rocks; and as these volcanic rocks were such as contain at the same time considerable quantities of alkalies, which were liberated contemporaneously with the clay, by the process of disintegration, and inasmuch as the clay exercises an immense attraction upon the former, we never find clay which does not contain a greater or smaller quantity of alkaline salts, and therefore never a soil in which alkaline salts could be entirely absent. Among the volcanic rocks which are especially rich in clay and alkaline silicates, are to be named: Granite, gneiss, syenite, mica-slate, basalt, lavas, and many others. The manner in which the disintegration of them takes place, showing a series of periods which are to be run through with before it is completed, is explained in a little pamphlet, of which my former Assistant is the author, and which was published as his inaugural thesis on his promotion to the grade of Doctor of Philosophy. As a matter of general and especially of highly agricultural interest, I have no hesitation in quoting here a short extract of his work:

"The rock of which 'the Kottenberg' in Germany is composed, furnishing the material for experiment, belongs to those numerous little basaltic cone mountains, which surround the large masses

of the 'Vogelberg,' and which probably at the same time broke through the triasformation with the latter. The mass of this basalt-cone is bent in a vertical direction in many fissures and caverns, which allow the rain water a free entrance into the interior. Probably in consequence of a successive disintegration which took place around a protected centre, the original rock had disjoined itself in three different concentric layers, the products of its disintegration, which in spite of going over into each other, were, notwithstanding, easy to be distinguished and were collected on the north-eastern end of the mountain, where a worked stone-pit permitted it.

1. The central mass had a black-gray color, which consisted of a mixture of felspar and augite. Only a few crystals of olivine were secreted in it, and which, by their brownish color, already indicated an incipient disintegration of the stone.

2. Upon the centre mass was lying a loose, much disjoined mass of light-brown color.

3. A light-yellow powder formed the outer and total disintegrated layer.

The stones under 1, 2 and 3, were then analyzed, and gave the following composition:

	1.	2.	3.
Silica,	54.45	48.79	43.26
Oxyds of Iron,	15.25	15.37	15.09
Clay,	12.13	13 82	17.51
Lime,	6.06	3.94	1.29
Magnesia,	5.81	1.24	1.17
Potash,	0.55	0.51	0.07
Soda,	3.68	2.72	0.12
Water,	2.14	14.33	22.61
	100.07	100.72	101.12

We perceive already by this account that silica, lime, magnesia and alkalies, were gradually washed out during the different periods of degradation; more apparent, however, will be the relative proportion of them, if we abstract from water and calculate their quantities for 100 clay, under the acceptation that clay had not been washed away, its full quantity had remained. We then proceed to the following scheme:

	1.	2.	3.
Silica,	448.71	353.13	247.01
Oxyds of Iron,	125.64	111.28	86.16
Clay,	100.00	100.00	100.00
Lime,	49.92	28.51	7.38
Magnesia,	47.90	8.99	6.71
Potash,	4.27	3.71	0.35
Soda,	29.67	19.77	0.70

The proportion of the quantities of Silica, Oxyds of Iron, Lime, Magnesia and Alkalies, which were washed out from (1) during its transformation into (2) is therefore the following :

A

		Oxygen.	
Silica,	95.58		50.58
Oxyds of Iron,	14.36	4.40	
Lime,	21 41	6.10	
Magnesia,	38.91	15.51	28.65
Potash,	0.56	0.09	
Soda,	9.90	2.55	

The proportion of the quantities of Silica, Oxyds of Iron, &c., which were washed out from (2) during its transformation into (3), is as follows :

B

		Oxygen.	
Silica,	106.12		56.13
Oxyds of Iron,	25.12	7.53	
Lime,	21.13	6.03	
Magnesia,	2.28	0.91	19.96
Potash,	3.36	0.57	
Soda,	19.07	4 92	

By subtraction of the quantities given in (3) from those in (1), we get the whole quantity of substances, which were washed away during both periods of degradation. Hence it follows the following composition in per cent. :

C

		Oxygen.	
Silica,	56.		29.1
Oxyds of Iron,	11.5	3.5	
Lime,	11.9	3.4	
Magnesia,	11.6	4.3	13.5
Potash,	1.	0.2	
Soda,	8.	2.1	
	100.0		

It will be seen that with advancing degradation the quantities of Silica and Lime decrease in a cónstant proportion, which is however not the case with Magnesia and Alkalies ; the former has been washed out almost entirely during the transformation of (1) into (2); whilst the greatest part of the latter had not disappeared till the transformation of (2) into (3) took place, consequently during the second period of degradation. The proportion between the quantity of Oxygen in the bases to that in the Silicic acid is

in (A) 1–1.7, in (B) 1–2.8, a proof that the Silicates, which were washed out during degradation, contained more silicic acid as the degradation advanced.

Not long ago, Ebleman* made experiments to investigate the changes which the Basalt undergoes from Lintz on the Rhine.—This Basalt was also disjoined by degradation into globulous and concentric masses around á centre mass of black gray color, which had not yet been attacked by water and atmospheriles. The analyses of them gave the following result:

	Fresh.	Disintegrated.
Silica,	45.9	43.2
†Titanic Acid,	1.0	1.2
Clay,	16.2	18.9
Peroxyd of Manganese,	0.3	0.3
Protoxyd of Iron,	13.0	14.6
Magnesia,	6.3	5.6
Lime,	10.3	8.2
Soda,	3.6	1.4
Potash,	1.2	0.5
Water,	2.4	6.7
	100.2	100.6

Or, calculated for 100 parts of clay:

Silica,	283	228
Titanic Acid,	6	6
Clay,	100	100
Protoxyd of Iron, Peroxyd of Manganese,	80	78
Magnesia,	39	29
Lime,	63	43
Soda,	22.2	7.4
Potash,	7.4	2.6
Water,	15	35

Hence it follows that during degradation the following quantities were washed out:

	D	Oxygen.	
Silica,	55		28.6
Protoxyd of Iron,	2	0.4	14.5
Lime,	20	5.7	
Magnesia,	10	3.9	
Potash,	4.8	0.8	
Soda.	14.6	3.7	

* Ann. des Mines, iv. Ser. T. xii. p. 637.

† Non-essential to vegetation.

The contemporary appearance of the large amount of magnesia and that of alkalies in D agrees neither with the relative proportion of the substances in A nor with that in B. It seems, however, proper to say that the substances in D were washed out within both periods of degradation, as represented by A and B. According to this acceptation, the silicate D had to show an analogous character with the silicate C, which finds indeed its confirmation by the proportion of the oxygen of the bases to that of silicic acid, which is in both an equal one, namely, 1-2; a proportion which is in the middle of both above mentioned, viz: 1-1.7 and 1-2.8.

We see by the above mentioned facts that the volcanic rocks, especially those which are rich in alkalies and clay, give away by the process of degradation a large quantity of potash and soda, combined with silicic acid, salts, which, by their solubility, are easily washed out by rain water, and then capable of penetrating the soils: whilst the remaining products of degradation become more and more of a clayey character, (the origin of all clayey compounds,) and poorer in alkaline substances and soluble silicic acid; that, however, the degradation never can advance to such a degree that the latter substances will be entirely washed out and consequently absent. All soils contain therefore soluble silicic acid and alkalies, on account of the clay present in them, which is one of their fundamental ingredients. Humus, as we have previously stated, possesses the property to retain alkaline substances and soluble silicic acid in a manner similar to clay. This may, to a certain extent, explain the reason of the fact, that the produce of the soil, other things being equal, is in direct ratio to its humus and clay.

From all, then, that has been said, from the known and ascertained condition of soils of known fertility; from the composition of crops that are grown for food; from the effects of the application of manures, it is to be concluded that the productiveness of a soil *to the extent of the production of the plant is due*:

1st. To the presence, in exact ratio, of the mineral constituents named above.

2d. The condition in which these substances are found as to their solubility.

3d. The capacity of the soil, as to its physical texture, to supply the growing plant with organic food from the atmosphere.

The proportion of the several mineral constituents best adapted to produce fertility and the requisite physical structure can be found, or at least approximated to, by a large

number of careful analyses made, in different seasons, of soils which are already productive. The kind and quantity of manures best adapted to renovate worn-out lands can be shown only by their careful analysis and the *noted* results of manures upon these lands. It is not enough to know that a particular manure is adapted to a particular soil. The most economical quantity, that which will give the greatest profit from the smallest outlay, should be shown, both as to present increase and future returns.

The above remarks lead us to the consideration of those substances which are used as

MANURES.

By manures are to be understood those substances which applied to soils, can either directly or indirectly supply plants with nourishment. This is a general definition of manures. It becomes special in reference to different soils, and they are then in this relation, whatever substances can supply the absence or deficiency of those constituents of the soil which are necessary to vegetation, either by supplying this absence or deficiency of themselves, or which by their action on the soil, can set free substances which may be present, but not in a form capable of assimilation by the plant. The most perfect knowledge, then, of the use of manures must be derived from a knowledge of their nature and composition, and also of the soils to which they are applied, and this is nothing more nor less than the science of Chemistry.

In the application of all manures particular attention should be paid to their equal and thorough distribution through the soil, so that each plant may have its due supply. In the selection of a manure, particular attention should be given to its mechanical or physical state. Many failures of manures are to be attributed not to the fact that the soil was not deficient in their constituents, but that the manure used was not in a fit state or condition when applied to the land to be used by the plant.

An acre of land contains 6,272,640 square inches; a pound av. 7,000 grs. It requires, then, about 900 pounds of any manure to supply one grain to each square inch of soil. If, then, in the application of 1,000 pounds of manure, say twenty bushels of bone dust or any other manure, and there be fragments of it weighing from one to two hundred grains, as is often the case, there must be in some places nearly from 1 to 200 square inches entirely destitute of manure.

In order to give to the soil manure in the proportion of

one grain to each cubic foot to the depth of 12 inches, we must apply about four tons. If we have the manure in large lumps, does not the least consideration show us that a large part of the soil must be left unmanured, even though we apply a very large quantity, a quantity too costly, frequently, ever to be employed?

Manure only can act in supporting the plant when it comes in contact with and can be taken up by its roots. How important is it, then, to have it thoroughly distributed, which is impossible except it be in the finest possible state of division. This should be looked to when large quantities of cheap manures are applied, more especially, then, when costly manures are used in small quantities. When, for instance, we apply two hundred pounds of guano, if it be not beaten up very fine, and then most carefully applied, a large part of the crop will receive no nutriment, while some will have too much, and although the appearance of the crop may be satisfactory, still there will be much less of it produced than if the manures were evenly applied. The above observations apply to compost, stable manure, and more strongly to lime, but with much greater force to guano, bone-dust and other expensive manures used in small quantities.

The great effects produced by bones in a state of solution are due to their thorough distribution in the soil; and we find that liquid manures, though containing but a small proportion of the necessary elements, yet, nevertheless, act with great intensity; this intensity of action is due to their *form* and to the fact that though every part of the soil may receive but a small portion, yet no part of it is left unsupplied.

Sir Gilbert Blane caused experiments to be made with flax water, which although containing a small portion of inorganic matter, yet acted very powerfully, a fact due to the complete solution of all the substances in it, so that when they were applied to land every part of the soil was supplied with some portion of it.

The *mode* of the application of manures is not sufficiently attended to in this country, though sometimes it is as important almost as the article used. Whatever this may be, the full measure of benefit from it cannot be obtained unless it be equally distributed, and this cannot be effected unless it be in the finest possible state of division.

LABOR IS NOWHERE SO PROFITABLY EMPLOYED as when *in reducing manures, before using them,* TO THE FINEST POWDER.

In another sense, manures are such substances as may be applied to soils in order to meet certain deficiencies that may either originally occur in soils in consequence of a defective

formation, or be produced in them by their continued cultivation. Substances of this class, capable of restoring, in the one or the other way, the lost fertility of a soil, are generally known as Manures or Fertilizers, and have been used from the earliest times, long before science enabled us to account for their beneficial action. It is my object to devote the following pages of this treatise to a description of the various kinds of manures employed, and to found upon the resulting facts a series of conclusions relative to their mode of action, and of recommendations in behalf of the most proper mode of action, and of recommendations in behalf of the most proper mode of their management, as best accord with both practical experience and the present state of science.

We still remember, from our knowledge of the functions of the soil, that its fertility depends on two factors: mechanical texture and directly nourishing capacity, the product being the crop. This fact stands in close relation to the wants of plants. The various single substances which serve as nutriments to plants, and which we find as constituents of their body, are naturally divided into two classes, viz: such as are capable of assuming the gaseous state and then form a constituent of the atmosphere—water, carbonic acid, and ammonia—and such as, by their involatility, are bound to the soil through which they are diffused in minute particles, and are not liable to loss unless assimilated by the plants and subsequently removed with the crop—I mean the phosphates, sulphates, chlorides and silicates of the alkalies and alkaline earths, or the mineral constituents of plants.

These latter substances, though they form a comparatively small part of the body of the plant, are nevertheless indispensable for the development of vegetable life; and it is the absolute quantity of these matters present which we regard as the totality of the directly nourishing capacity of the soil. The means by which they may be supplied to soils deficient in them are given to us in various forms, as bones, mineral phosphorites, Mexican and Columbian guanos, super-phosphates, ashes, common salt, plaster of Paris, &c.

The former class of substances, on the other hand, furnish the material for the main body of the plant, inasmuch as the whole of its combustible or organic part is formed from the constituents of these nutriments. Their supply depends to a large extent on the mechanical texture of the soil; for it is the particular proportion in which the fundamental constituents of soil (sand, clay, lime and humus) are present, which causes a more or less perfect communication of the soil with the atmosphere, which furthermore promotes the formation

of these very substances in the body of the soil itself, and which also exercises an attractive power for these nutriments, and retains and reserves them if they have once become appropriated by the soil.

Among them, *water* is the most common and abundant, for the supply of which nature provides in a liberal manner. But in spite of its being met with almost every where in nature, we are well aware of the fact that it is not seldom wanted, and then usually at a time when the plants need it most urgently for their final development. The injurious effect of dry seasons on *present* crops is well known. On the other hand we meet soils entirely destitute of productiveness, and find, upon examination, that their sterility is the consequence of their wet condition, they being saturated with moisture, and even permit the water to rest upon them and to remain there for a considerable length of time. If by some means the water is removed from this kind of soils, they are at once rendered fertile and fit to reach the highest state of culture.

This state of things shows clearly that the water, though a nutriment to plants that cannot be dispensed with, is nevertheless, to the highest extent injurious to vegetation, if permitted to accumulate in the soil; and as the condition of the soil, as a body at large, is due to its mechanical texture, or to the proportion in which the fundamental constituents are present in it, it follows that a regular supply of this nutriment, neither more nor less than wanted, can only be secured by a proper mechanical texture of the soil. In this case the soil will, at one time, reserve to the utmost, the needed quantity of water, whilst at another, it will freely dispense with all superabundance.

The quantity of water required by plants during their growth is very considerable. It is the medium by which all other nutriments are conveyed to the plants, and with which they dispense again as soon as this function has been fulfilled. Boussingault states that annually by a good crop from one acre, about six millions pounds of water evaporated from the leaves of the plants that was previously taken up by their roots. Besides, plants contain about 12 per cent. of their weight of water in the dry state, which forms a constituent part of their body.

Carbonic acid, the second of this class of nutriments, is the substance from which plants derive all their carbon, or about 43 per cent. of their whole weight. A regular supply of carbonic acid is likewise dependent on the mechanical texture of the soil; for carbonic acid is the product of the decomposition of humus, a substance which forms a fundamental con-

stituent of soils, without which a proper mechanical texture cannot exist. Where there is no humus in the soil, no proper mechanical texture exists, nor can there be any regular source for the supply of carbonic acid to meet the wants of the growing crop. The supply of carbonic acid is, in truth, not altogether dependent on the condition of the soil itself, as is the case with water, which enters the system of plants exclusively through their roots, and therefore always by the medium of the soil. Independently of this manner of assimilation, carbonic acid is also taken up by the plants, to a large extent, directly from the atmosphere by the medium of their leaves. It has even been proven by experiment that plants can be raised in a soil entirely destitute of humus, in which case they are solely referred to this latter mode of appropriating their carbon. This state of things, however, merely shows to what extent plants can be forced to feed themselves in a partial manner, but in no way prove that under this condition their development is the most prosperous. Experience teaches us, on the contrary, that the co-operation of the humus in the soil is indispensable for securing a regular supply of carbonic acid to plants, and their production in the most perfect form. The gas arising from the humus furnishes a constant source of carbonic acid for that portion of the atmosphere which immediately rests upon the soil and surrounds the upper part of the plant. It also thoroughly penetrates the soil itself, in the very body of which it is produced, becomes there dissolved in water, and in this form most fit to enter the rootlets of plants and to provide thus a nutriment which plants, in their first period of life, cannot appropriate to themselves otherwise, being without leaves at that time.

A regular supply of carbonic acid for the whole term of the growth of the plant can therefore be secured only by the co-operation of humus, or what is the same, by a proper mechanical texture of the soil, and experience teaches us, in accordance with this, that the beneficial influence of the humus on the production of crops is so great that two soils of equal capacity will, *mutatis mutandis*, yield average crops in proportion to the quantity of humus they contain.

Ammonia, finally, is the substance from which the plant derives all its nitrogen, or about one per cent. of its whole weight. It is, like carbonic acid, a product of the decomposition of organic matter, and therefore most intimately connected with the occurrence of humus. Far the greatest mass of the organic part of plants consists of carbon and the elements of water, (hydrogen and oxygen,) and becomes con-

verted into humus as soon as the vital powers have ceased to exist in it. But there is a series of other organic compounds present in the plant, which, besides the above named elements, contain nitrogen as a constituent part; and as these compounds form the real nutritious matter of the vegetable food by being converted into blood, and subsequently applied to the production of the organs of the animal, they must necessarily accumulate in the animal body and re-appear in a more concentrated form in the carcass or the excrements of animals than they occurred in the body of the plant where they originated. These compounds, whether still existing in the plant or already transformed into constituents of the animal body, when they undergo a process of decomposition, produce humus, and, besides, evolve ammonia in proportion to the quantity of nitrogen they contain. The ammonia becomes partly disengaged and is then diffused in the atmosphere, and is partly retained by, and incorporated with, the humus which is simultaneously formed with it.

The atmosphere, which is thus constantly supplied with ammonia from organic bodies wherever existing in a state of decay, contains this substance in a considerable quantity, and, to judge from the result of analytical examinations of the atmosphere, sufficiently even to meet the wants of all the growing crops on earth. Practical experiments have also proven, in accordance with this fact, that plants can be raised and brought to perfect development without the aid of any other source furnishing ammonia but the atmosphere; and if the experience of practical farmers advise us *not* solely to rely upon this source, but to take care, besides, of keeping the soil itself well supplied with it, by means of artificial applications of such manures as are capable of producing it,—it is for reasons which are founded upon the same principles that have been discussed already in their relation to the supply of carbonic acid.

An experiment on the production of plants under given conditions for the solution of certain questions, is altogether different from the practice of producing crops, and the conditions under which it can be most satisfactorily effected. In the one case, we investigate to what extent plants can be forced to live on a partial supply of the necessary elements, and judge from the more or less perfect development of all their parts, whether we have to decide in favor of the one or the other doctrine; in the other case, we are anxious to offer to the plant an abundance of its elements, by opening the most various resources for its supply, and estimate the result, not from the fact that the produced plant shows a root, a chaff,

and bears seeds in a normal way, but by the quantity of grain and straw which the acre has actually yielded, and thus reduce it to a mere question of dollars and cents. This difference in object and success of two practical pursuits of similar character, is the more necessary to be observed and fairly to be distinguished, as their identification has principally originated the apparent but erroneous contradictions that have been supposed to exist between the results of practical experience and the laws of scientific agriculture. A soil which contains all the requisite nutriments for plants but ammonia, or such matters as are capable of producing ammonia, is, as to its productiveness, equal to a soil which contains all the nutriments without exception, but its mineral constituents in a state of combination which makes them unfit for ready action. Plants growing upon the one are solely referred to the supply of ammonia from the atmosphere, and the progress of their development must therefore be in a strict ratio to the quantity of ammonia thus furnished to them; whilst the growth of the plants upon the other soil, rich in ammoniacal compounds, must necessarily depend on the advancement of the degradation of its mineral constituents, and is consequently in proportion to the quantity of soluble salts, which become liberated by this process. Now, if direct experiments have shown that the plants on both soils will once reach maturity and become normally formed, it certainly proves that there is enough of ammonia in the atmosphere to support vegetable life, and that beyond doubt, the ammonia of the atmosphere takes a specific part in the nutrition of plants generally. But there is, at the same time; no reason to suppose that this result of observation, because true in itself, should dictate the rules for practical operations unless scientific agriculture be contradictory to practical farming. If this result is, in fact, of no applicability in practice, it merely proves that the development of plants should not be made dependent on the supply of the necessary substances, but that, on the contrary, an abundance of the necessary substances should at once be offered to the plants, in order to enable them to regulate themselves their supply, according to their state of development; a conclusion which relates most particularly to the plants we cultivate, inasmuch as they have to reach maturity within a certain period of time, or will fail entirely to do so. The spirit of Liebig's mineral theory, against which this objection has been repeatedly raised, makes in no wise the fertility of a soil dependent on its mineral constituents exclusively, nor does it attribute to them any preponderance over ammonia in re-

gard to their importance as nutriments; it only demands the acknowledgment of their equal significance as matters indispensable to vegetable life; and as the mineral constituents can only be supplied by the soil itself, whilst the sources for ammonia are various; it recommends such a system of manuring as is in best accordance with these facts. If we apply ammonia to the one of the soils above referred to, and soluble mineral salts to the other, we restore an equilibrium of the nourishing substances in both soils, and by so doing render them productive in the very spirit of the mineral theory. But we also know that the same result can be effected by putting both soils in the fallow until the one has appropriated to itself the required quantity of ammonia from the atmosphere, the other that of soluble mineral salts, as produced by the steadily advancing degradation of its mineral constituents. A soil which has become deficient in ammonia may, therefore, once regain its fertility without any artificial application being made to it; as can also a soil which is deficient in soluble mineral salts, but contains such constituents as will produce them by their degradation; whilst a soil which has no mineral constituents whatever, will remain unproductive until it is artificially supplied with them by nature.

In practice, where we cannot wait until the soil has recovered its nourishing ingredients by its own exertions, we have to apply both ammoniacal and mineral manures to restore its fertility; and if we choose to apply only the latter, with the expectation that the ammonia required would be furnished by the atmosphere, we would be acting just in the same way as if we had added ammoniacal salts alone to a soil deficient in soluble mineral salts, with the expectation that they would be furnished in time by the process of degradation. In neither case will our expectations be realized in practice, nor are they in compliance with the spirit of the mineral theory.

Lawes' and Gilbert's observations illustrate most remarkably the importance of ammonia as a nutriment for plants. They found that the more of nitrogen we apply to a soil by manure, the less is its quantity in the grains of the wheat crop raised upon it; and as the absolute quantity of nitrogen of the whole crop, in toto, is augmented in proportion to that of the soil, it naturally follows that these extra additions made, increased to such an extent the weight and number of the grains, as to effect even a decrease in their *per centage*, or *relative* quantity of nitrogen. Besides, we know by the statements of these agriculturists, that the market price of

wheat depends almost exclusively on the quantity of nitrogen in the grains; those containing relatively the least of it, being at the same time the most perfectly developed; they are the heaviest, largest in size, and produce the finest quality of flour. The application of nitrogen to soils, (in the form of ammonia,) therefore, not alone increases the yield of the crop far above the proportion which we at first should anticipate; but it also improves the quality of the produced grain, and thus secures for it the highest price in market.

It has already been remarked that the quantity of ammonia which a soil contains, or is capable of producing, is generally in proportion to the quantity of humus in it. This latter substance, though free of nitrogen itself, is always accompanied by nitrogenous matters, which, as integrant parts of the plant, necessarily decay with its whole body, and becomes thus intimately incorporated with the humus produced. The nitrogen amounts to about 1-15 of the quantity of carbon of which the humus is composed.

But there is, independently of the supply of ammonia by humus, another source for the acquisition of this nutriment, which is inherent to the body of the soil at large, and therefore also dependent on the mechanical texture of the soil. It has been proven that all soils have more or less the property of attracting the ammonia contained in the atmosphere, and to retain it in a state of combination, which so tightly locks it up in the body of the soil, that it is impossible to extricate it again with water. Water even, which has been saturated with ammoniacal salts, if suffered to filter through soil, runs off clear at the expense of the ammonia formerly contained in it; as also an atmosphere charged with gaseous ammonia is deprived of it when brought in contact with soil. In all these cases the ammonia is found to have been appropriated by, and incorporated with the soil. Prof. Way recently discovered by his most tedious labors, that a certain class of artificial double silicates exercise, in this respect, a power similar to that of soils, and, for several reasons, he concluded that it was to the presence of portions of these double silicates that soils owed the power above alluded to. Among them the double silicate of lime and alumina was found to be that to which this absorptive power of soils has chiefly to be attributed; this substance is a constituent part of clay, through the mass of which it is diffused in minute particles, and therefore never absent in soils. But if, in accordance with the above, the power of soils for absorbing ammonia is increased with the quantity of clay in them, it is on the other side necessarily lessened again in proportion to the degree of stiffness

they assume, at the expense of their porosity and fitness to communicate freely with the atmosphere, and is, therefore, also dependent on the mechanical texture. Direct experiments have shown that the mechanical texture of loamy soils is the most favorable for the performance of this important function of soils; this class of soils, though containing a considerable quantity of clay, is famous for the porous condition of its body, in consequence of which it will permit a free access of the atmosphere to all its parts.

The means and ways for the improvement of the MECHANICAL TEXTURE of soils are various; it may be effected either by a mechanical treatment of the soil itself, as by loosening, deepening, draining, &c., or by extra additions being made to it from without. Of these two methods of improvement, only the latter is an act of manuring in the strictest sense of the term, and subject to our consideration in this place. The substances applied are such as will meet the deficiencies of the one or the other of the fundamental constituents of soil, and in this way restore a proper proportion of their relative quantities. In accordance with this, they may be divided into four classes of manure, viz: silicious, (supplying sand;) argillaceous, (supplying clay;) calcareous, (supplying lime and magnesia;) and organic matter, (supplying humus.)

After the foregoing remarks, I will now treat, in particular, of the various kinds of manure employed, whether designed for the improvement of the mechanical texture or for the purpose of increasing the directly nourishing capacity of soils, and will present them in an order which, if not strictly systematical, will best lead to a full understanding of their character and mode of action.

NITROGENOUS MANURES.

Stable or *barn yard manure* is indisputably the chief manure of all, as it offers to the farmer the most natural and efficient means for restoring fertility to his soil. It is formed of the solid and liquid excrements of animals, together with the litter-straw of wheat or indian corn, and is consequently composed of both classes of fertilizing substances; those which, by their physical properties, improve the mechanical texture of soils, as well as those which, being soluble in water, serve as a direct nutriment to plants.

With regard to the former, stable manure acts principally on account of its humus, the high importance of which as a fundamental constituent of soils, has been repeatedly discussed in this and my former reports. Humus promotes the

absorptive power of soils for the gases. It keeps the soil warm and at a constant degree of temperature, and, like clay, aids materially in retaining its moisture. But instead of increasing the stiffness of soils as clay does, it renders them, on the contrary, porous and friable, so that the more a soil contains of humus, the more of clay can it contain without becoming close and difficult to be plowed. Its principal feature, however, is its intimate connection with nitrogenous compounds, the transformation of which into ammoniacal products advances statedly with the decomposition of the humus. In this way, humus furnishes to the plants, besides water and carbonic acid, (the product of its own decay,) a constant and appropriate supply of ammonia to the very last of its existence.

As to the latter, (the directly nourishing substances,) it is evident that stable manure contains all the nutriments that were once extracted from the soil by plants, and subsequently removed from it with the crop, and that its application to the soil is therefore simply an act of restitution, at least so far as it concerns these particular matters. The experiments made by Boussingault with grown animals, by a feeding not more than necessary for their sustenance, have in fact, directly proven the identity of the ultimate composition of the food consumed, and of those matters which in the meantime, were ejected from the animal body, as also their equal absolute quantity, if calculated for a certain period of time, at the beginning and end of which, the weight of the animal remained stationery. The totality, however, of the matters ejected from the animal body is in no way fully represented by the solid and liquid excrements alone; we know that a considerable part of these matters (amounting to about 2-5 of the whole) are evolved in the form of water, carbonic acid and ammonia, from the lungs and through the skin of the animal, by the process of breathing and perspiration. These substances being volatile, are diffused in the atmosphere, and consequently waste a large portion of the food, by the transformation of which, under the process of life, they were produced; and it is only the remaining portion of the food which reappears in the form of solid and liquid excrements, and such other substances as milk, &c., as may be collected by the farmer, and thus be of direct benefit to him.

From these facts, relative to the connection between excrements and food, we may judge, *a priori*, of the most probable composition of the former. We have seen that carbon, hydrogen, nitrogen and oxygen, the constituents of the organic portion of food, become partly separated from it in the animal

body, and are evolved in the form of water, carbonic acid and ammonia. The other portion of the food which furnishes the material for excrements, must, therefore, necessarily contain less of organic matter, and as the whole amount of the inorganic constituents remain undivided with it, relatively more of mineral matter than the original food from which it is derived. An examination into the ultimate composition of both, as found by direct analysis, proves the correctness of this conclusion beyond doubt, and discloses, besides, a fact which at once appears interesting and important in its relation to the efficiency of stable manure as a fertilizer. It is the fact, that the excrements of animals contain relatively more of nitrogen than the food from which they are derived, or in other words, the processes of life transform the food when passing through the animal body into a series of compounds which contain the nitrogen in a form the more concentrated, the more they approach their ultimate destination and final composition. We have seen before, that a portion of the organic part of the food which evolves in the form of water, carbonic acid and ammonia, is all that is subtracted from it whilst under the influence of the vital powers; here we find that, in consequence of this very process, the remaining part, that which furnishes the material for excrements, has increased its quantity of nitrogen far above the prop or tion in which it originally constituted the food. What is the cause, we ask, of so close a connection of two facts, apparently contradicting each other? It admits of but one explanation, as it indisputably proves that the relative quantities of water, carbonic acid and ammonia, as they are evolved from the lungs and through the skin of the animal, do in no way correspond with the proportion in which their ultimate constituents, carbon, hydrogen, oxygen and nitrogen, have originally formed the component parts of the food; there is, in the form of carbonic acid and water, more carbon, hydrogen and oxygen evolved, and consequently, in the form of ammonia, less of nitrogen than it would be the case if the different constituents of food had equally participated in the production of these substances.

In recapitulation of the different processes above alluded to, to which the animal food is subjected whilst under the influence of the vital powers, we may accordingly collect the following conclusions relative to the composition of the excrements if compared with the composition of the food from which they were derived:

1. The absolute quantity of the excrements derived from a certain quantity of food, amounts to not more than about three-fifths by weight of the latter.

2. The absolute quantity of carbon, hydrogen, oxygen and nitrogen in the excrements, is less than their absolute quantity in the food.

3. The absolute quantity of mineral matters is equal to that contained in the food.

4. The per centage (or relative quantity) of mineral matters in the excrements is higher than in the food; and finally,

5. The per centage of nitrogen (that substance which is capable of producing ammonia) is also higher (about double) in the excrements than in the food.

This much as to the relations between food and excrements, so far as they are founded on the ultimate composition of both, as well as on the peculiar changes to which the food is subjected in the animal body. With it we now leave the matters as they occur in the living animal, under the influence of the vital powers, to themselves, and turn next our attention to the changes which occur in the excrements when without the animal body and exposed to the influence of atmospheric air; I mean to say, to the changes they undergo by the process of putrefaction.

The excrements of animals soon become intimately mixed with the litter straw of the stables, and remain in this state, at the barnyard, sometimes for months, before being applied to the soil as manure. The reasons for such a delay in the application are, in no wise, to be attributed to a negligence on the part of the farmer, nor are they altogether conditioned by the necessity to await the proper season for manuring. A *rational* husbandman, one who works understandingly, is besides well aware of the fact that barn-yard manure, in its different phases of putrefaction, will exercise very different effects on a particular kind of soil, and knows by experience how far its decomposition has to advance to suit best the soil to which he intends applying it.

It is a well known fact that organic bodies, over which the vital powers have ceased to exercise a control, becoming exposed to the simultaneous influence of air, moisture and heat, will decompose and consequently decay. We say they are "rotting," if no stinking effluvia be evolved from them; and this is the case with all those which are composed of no other elements but carbon, hydrogen and oxygen. Wood-fibre, of which the principal mass of plants is made up, is a representative of this class of organic matters, and its decay consists simply in a slow combustion, (eremecausis,) produced by its uniting with atmospheric oxygen. Under these circumstances, carbon and hydrogen, the constituents of the fibre, become

gradually transformed into carbonic acid and water, whilst that part of the fibre which remains, in the course between the first start of decay and final destruction, runs through many phases of decomposition, and represents in this form that which we call *humus*.

The term "putrefying," on the other hand, is applied to the decay of such organic compounds as are noted for the disagreeable and penetrating smell they evolve, and this is the case with all those which contain, besides the above named elements, nitrogen as a constituent part. Small quantities of sulphur and phosphorus also generally accompany them. Urea, the chief constituent of urine, may be regarded as a representative of this class of organic matters, and we may find at once, that its decay or putrefaction differs somewhat from the process mentioned before, as it does not altogether consist in an oxydation of its carbon, hydrogen and nitrogen, at the expense of the atmospheric oxygen. Urea becomes gradually transformed into gaseous carbonic acid and ammonia, of which the former carries away all the original carbon, whilst the latter embraces the whole of its nitrogen and hydrogen. But there is originally not enough of hydrogen in urea so as to combine with the whole of its nitrogen to form ammonia, and the balance must therefore necessarily be furnished by some source from without. In accordance with this, practical observations have shown that it is water to which this important function has to be attributed; the presence of moisture being, as we know, one of the conditions for putrefaction. The water, most remarkably, suffers a gradual decomposition itself, when in contact with the putrefying substance, and becomes thus divided into its elementary constituents, hydrogen and oxygen, of which the former, at the moment of its being liberated, unites with any excess of nitrogen to form ammonia, whilst the latter, in common with the oxygen of the atmospheric air, transforms the whole of the carbon into carbonic acid.

Returning to barn-yard manure, it is evident that we have both classes of organic matters, the rotting and putrefying principles, fairly represented in its composition. There is the litter-straw of wheat or Indian corn, nearly identical with wood-fibre; and on the other side, intimately mixed with the former, the various nitrogenous compounds, (including urea,) as they occur in the solid and liquid excrements of animals.

Left to itself for a sufficiently long time of exposure, barn-yard manure may, therefore, become wholly converted in'o water, carbonic acid and ammonia, and will then,

then, with the exception of its mineral constituents, entirely disappear from the ground. This effect is, as we know, actually produced in the body of the soil to which stable manure is applied; our experience teaching us that, in the course of time, no trace of it is left in the soil; but as this final term of existence is, in no-wise, intended to be reached at the barn-yard, we may here freely dispense with its consequences as no subject for discussion in this place. All that we desire, for the present, to arrive at, is a knowledge of the changes which stable manure undergoes by putrefaction at the barn yard, or within a certain period of time previous to its being applied to the soil. The pecularities of these changes will best become apparent by a single comparison of the composition of stable manure, when in its fresh state, and after having putrefied under necessary precautions. From the result of direct analyses, the following conclusions may at once be drawn:

1. Water, carbonic acid and ammonia, being evolved in the course of putrefaction, reduce the absolute weight of the manure, and thus increase, relatively, the quantity of the involatile portion, or its mineral constituents.

2. There is relatively more of carbonic acid and water evolved, and less of ammonia, than is in proportion to the quantities of carbon, hydrogen, oxygen and nitrogen which constitute the manure. The quantity of nitrogen is, therefore, relatively increased in the putrefied manure. And finally:

3. Inasmuch as a part of the oxygen has directly combined with hydrogen and departed in the form of water, the quantity of carbon became also relatively increased, and thus effected a partial change of the original light color of fresh stable manure into the brown, or even black color of that which is putrefied.

These conclusions are very similar to those which we have formerly expressed in relation to the composition of food and excrements; the final products of both processes, of digestion and putrefaction, being richer in nitrogen and mineral matters than the original substances from which they were derived,—the one process is *quasi* a continuation of the other, both producing identical changes. Indeed, the ultimate compositions of food and excrements, fresh stable manure and putrefied barn-yard manure, bear exactly the same relation to each other, and prove, besides, that in each case an entirely new article is produced, provided with specific virtues of its own. Thus barn-yard manure, when putrefied, differs materially from fresh stable manure in composi-

tion, character and mode of action; and it is but owing to our present knowledge of these relations that we may henceforth rationally decide whether the one or the other kind should be used for the improvement of particular soils.

It is apparent that soils of a proper mechanical texture, such as are, to an equal extent, both binding and porous, which furthermore possess the required power for retaining moisture without permitting, however, an injurious accumulation of water in their body; which also have the capacity of absorbing and retaining gases, or show, in general, such qualifications as are marks of a high state of culture, and more or less characterized by the presence of a proper quantity of humus in them; it is apparent, I say, that soils of this description will be more benefited by the application of the putrefied than fresh variety of stable manure. The latter may even act injuriously on the condition of these soils, by increasing the quantity of humus already contained in them, far above the proportion which is considered to be proper and most fit for prospering vegetation; whilst the putrefied stable manure, which in the course of putrefaction has lost most of its humus, will supply nothing but the deficiencies of ammoniacal and mineral matters that may occur in these soils, and with them, all that these soils want for being restored to fertility.

All classes of soils, with the exclusion of their extremes, such as stiff clays and light sands, possess more or less the properties above alluded to, or may easily obtain them by their own exertions, in a regular course of cultivation. For all these the application of putrefied barn-yard manure is the most advisable and rational. This is not less the case with regard to the improvement of meadow land. Here is no loosening, nor any other mechanical effect intended to be produced for the purpose of improving the texture of the soil, and the application of humus, therefore, of no use whatever. A manure for meadow land is rather expected to contain a maximum of directly nourishing substances in a form ready for assimilation, and as it can only be applied as a top dressing, to possess such physical properties as will most facilitate its uniform distribution over the ground. In both respects, the putrefied manure deserves the preference. It contains, as we know, its fertilizing principles in the most concentrated form, and being, besides, reduced to a state of great fineness and subdivision, offers advantages, as to its management, which fresh stable manure, on account of its coarseness, cannot equally present.

Stiff clay soils and light sandy soils, on the contrary, re-

quire, first of all, a change in their mechanical texture; and here fresh stable manure affords the best means on hand to meet the deficiencies in this respect. The humus which it contains in considerable quantity, will render the clay soil more voluminous, loose and porous, and thereby fit to communicate freely with the atmosphere; also, by generating a slow and regular evolution of carbonic acid in the very body of the soil itself, it will, to some extent, compensate the inability of these soils of appropriating carbonic acid from without. Light sandy soils, on the other side, which suffer mostly by an excess of dryness and heat, the necessary consequence of the predominance of quartz-sand in their body, obtain, likewise, in humus, a most valuable fundamental constituent which will impart to them the power of retaining moisture and soluble nutriments; and as it envelops and joins the quartz-sand particles, materially aid in tempering their excessive power of absorbing heat. The immense benefit which is derived from the practice of manuring with green crops, is most apparent on these latter kinds of soils; they, very properly, are usually turned in with the stiff clay soils, whilst their application in the form of a top dressing is generally adopted for the improvement of the light sandy varieties. This is an indirect proof for the correctness of the views, as laid down in the foregoing; the application of a green clover ley being, indeed, in every respect, a substitute for a dressing with fresh stable manure.

Coarse stable manure should always be applied as a top dressing to young clover in its second spring, we then obtain its advantage with compound interest, it greatly increases the clover growth, which in turn greatly increases the growth of wheat, or any other crop which may succeed it. As to the propriety of this plan, there can be no two opinions.

The last, and in a practical point of view, the most important matter to be discussed, is the manner in which stable manure should be preserved so as to secure the most beneficial results from its use. The conclusions which we have drawn above, in relation to the composition of both putrefied and fresh stable manure, are only correct when the proper precautions have been taken to preserve it and to regulate the process of its putrefaction. When this is attended to, practice and scientific investigation have shown that there occurs little or no loss in its valuable fertilizing constituents. Every man of common sense must admit that the rules to be adopted for a rational system of saving manure, must be based on the knowledge of changes that occur in the course of its putrefaction, and it is in accordance with our present

knowledge of this process that we may lay down the following rules in relation to it:

1st. The ground selected for the deposition of stable manure should be even, in order to permit the equal distribution of the manure on it, and thus secure to the heap uniformity in thickness. Only in this case the process of putrefaction will proceed regularly in every part of the heap, and its body will prove to be of a homogeneous character.

2d. The manure should be protected against the direct rays of the sun, in order to prevent the too rapid advance of the putrefactive process, and a consequent generation of heat which will incur a considerable loss of ammonia. Practical experiments made with equal weights of stable manure exposed to the sun, and with that under cover, show the effect of the latter to be, within a certain time, about twenty-five per cent. greater than the former.

3d. The manure heap should be kept moderately moist; if it be too dry, the degree of heat then produced will volatilize ammonia; if too wet, an acid humus will be formed which, being soluble in water, acts very injuriously on vegetation. In order best to attain this end the ground should be slightly inclined, and all the fluid that runs from the heap be collected in a pit, from which it may from time to time be scattered over the heap.

If the above rules are strictly observed, and the necessary arrangements which they require to be made, fairly provided for, no other precautions need to be taken for securing the highest possible effect of this manure. The practice of applying plaster of Paris, copperas, or sulphuric acid, for the purpose of fixing the volatile ammonia, is then unnecessary and may best be entirely dispensed with. Indeed, the sulphate of lime, whether directly added in the form of plaster of Paris, or subsequently produced in it by the application of the other two substances, will be of good service only in the case that enough of water is present to favor the formation of sulphate of ammonia (a fixed ammoniacal salt) on one side, and of carbonate of lime on the other. If, on the contrary, the heap should happen to remain dry for some time, the effect produced by such applications will be quite the reverse. Carbonate of ammonia is then evolved and sulphate of lime regenerated; and a neglect of attendance to this condition, therefore, much harder felt than when no applications of this sort have been made to the heap at all.

We have thus far, exclusively treated of the organic part of stable manure, particularly of its composition and the changes to which it is subject by the process of putrefaction.

With regard to the inorganic part, or mineral portion of stable manure, it is evident from its origin that it must be composed of all the various constituents requisite to the development of vegetable life, and to contain them in a quantitative proportion best adapted to meet the wants of the growing crop. This state of things, though sufficient in itself to justify the most favorable expectations, gives nevertheless, no full exposition of all the virtues of this valuable part in stable manure. There are besides, two other instances to be mentioned which add materially to its efficiency as a fertilizer, and secure to it its acknowledged superiority over all other mineral compounds that have been brought in competition with it. The one relates to the particular form, the other to the state of association in which the mineral part exists in the great mass of stable manure; both acting most powerfully in promoting its assimilation by the plants. For being, as to the first instance, only a small integrant part of the whole voluminous mass of the manure, it must necessarily exist there in a state of indefinite fineness and subdivision, and therefore, most liable to yield to the action of solvents. And if we ask what solvent should probably most powerfully act on the constituents of the mineral portion of stable manure, we must, according to the results of practical experiment, answer in favor of water impregnated with carbonic acid, the very substance which is furnished by the second instance, that is, in consequence of the intimate connection of the mineral matters with the organic part of stable manure.

The humus, as we know, provides during the whole course of its decay, for a regular source of gaseous carbonic acid, which, in the moment of its being evolved from it, is most liable to become incorporated with the water contained in the soil, and thereby to impart to it the power of dissolving freely the earthy substances of which the mineral portion of the manure is composed.

These conditions demonstrate at once the highly fertilizing properties of the mineral portion which, in its connection with the organic part, in the form of stable or barn-yard manure, must really offer the most natural and efficient means for restoring fertility to soil. No temptation, however ingeniously displayed, should induce the farmer to lessen his appreciation of this valuable fertilizer. He should aid, improve and increase it by all means, but never neglect or distrust it, for it is his nearest and best friend on whom he can call in his hour of need, and who will give him not grudgingly increased crops, and impart increased fertility to his

soil. Let not foreign manures of any sort, nor those *manufactured* in our midst, however pompously advertised or extravagantly puffed, be substituted for it.

Stable and barn-yard manures must be the main dependence of the great body of our farmers. Do not then let it be neglected. Treat it as I have shown above, and there will be less reason for our farmers to submit to the extortions of foreign or domestic manure dealers.

Peruvian Guano stands, as to composition and character, next to stable manure, particularly to that which is in an advanced state of putrefaction. It contains but a small quantity of humus, the whole of its organic part, amounting to 50 per cent., consists of nitrogenous compounds, capable of yielding, in the course of putrefaction, about one-third of their own weight of ammonia. The balance being about 40 per cent. of mineral matters, mostly phosphate of lime, and 10 per cent. of water. This composition shows at once the article to be a highly concentrated manure; it is, in fact, the most concentrated of all fertilizers of commerce; and practice has long since given abundant evidence in its favor. I have repeatedly spoken of Peruvian guano in my former reports, as to its composition and the particular substances on which its fertility depends; this I need not here repeat, as it is well known, and will only refer for information on this subject to my former reports. The collection of more numerous facts and the results of more experience, however, induce me to make some remarks as to its mode of application and the *quantity* which should be used.

This is the more necessary as some of the sources from which our farmers seek information are dealers in the article, and are therefore not disinterested, even if they were from practical experience or scientific knowledge competent advisors. This is not the case, and we therefore have ignorance and selfishness combined to mislead the farming community in the use of this article.

With regard to its application, it must be urgently recommended; first to use an article which is either originally in a state of fine comminution, or rendered so previous to its application, by sieving and subsequent pounding of the selected lumps, or by being ground in a proper mill; and, secondly, to sow it in a manner which will secure its distribution throughout those parts of the soil *where* the grain is sown; to effect this purpose, it on grain crops should always be sown with a drill. It is apparent that Peruvian guano, on account of it containing nitrogen not alone in the most concentrated state, but also in a form (that of the volatile ammo-

nia) which renders it extremely volatile, is more liable to loss than any other of the manures commonly used; and that, therefore, our particular attention should be directed to the ways and means by which its full effect may be secured.

There is, in fact, but one substance which, if properly mixed with this guano, will in every respect answer the purpose in question, and this substance is soil itself. It has already been remarked that water which has been saturated with ammoniacal salts, if suffered to filter through soil, runs off clear without the ammonia formerly contained in it, and that this power of soils, of retaining the ammonia, has to be attributed to the presence of portions of double silicates in them. This power of soil comes here into action, and it is plain in itself that its effect on the guano will be the more thorough and full the more uniformly the guano has been distributed throughout its mass. In order to attain this object, it may be advisable to mix the guano, previous to its application, with a suitable quantity of soil, (about double its weight,) especially in the case when the quantity of Peruvian guano to be used is too small to allow its uniform distribution over the surface of the acre to be manured. The soil best adapted for this purpose should be a loose, loamy one, and rich in humus, so as to secure to it a specific gravity, not exceeding that of the guano to be mixed with it; a perfect mixture of two substances being possible only when they are of equal gravity, and only in this case they will not separate from each other when being sown.

The second point to which I shall direct the attention of farmers, is to the quantity of guano which should be applied per acre. *My own practical observation, as well as that of many others who followed my advice, has decided that it should never go beyond two hundred pounds, but may for many soils, according to their degree of stiffness, fall short of one hundred pounds, and this should always be applied with a drill.*

There is further advice which I must give in relation to the use of Peruvian Guano as to the crops to which it should be applied; as a general rule it should be applied to the narrow leaf plants, such as wheat, oats and rye, in the largest quantities. Plants absorb much of their ammonia from the air, the smaller the leafy surface, the greater need is there consequently for a larger supply of ammoniacal manures to plants of this class, than to those which have a broad leafy surface, such as tobacco, cabbage, corn, &c.

It has ever been my endeavor to diffuse amongst farmers the true philosophy of farming, and to make them understand that crops cannot profitably be increased by enormous

additions of Peruvian guano, nor of any other manure, as has been advised.

This law is correct, that the yield of crops is not in direct ratio to the quantity of any substance either originally existing in the soil or applied to it by a manure, but on a proper proportion of all the elements of the food of plants. Crops cannot, therefore, be economically produced by the application of three or four hundred pounds of Peruvian guano, as has been recommended by some who assume to direct agricultural improvements, without either practical experience or scientific knowledge. If we go beyond a certain quantity, the crop will not be increased in proportion to the expense of the surplus added, and this large application will consequently be unprofitable, save to the manure dealers. The application of 200 pounds of Peruvian guano, *containing compounds capable of forming sixteen per cent. of ammonia,* is enough for any soil, and on many soils a less quantity is all that is required; and the effect of this, if used according to the directions which we have given, will equal in effect double or treble this quantity improperly applied.

This advice has heretofore saved thousands of dollars to the farmers and planters of our State, and if followed will save many more thousands. They should not make up for *other deficiencies* in the soil by the application of large quantities of a manure so expensive as Peruvian guano.

Nitrate of Soda—Chili Saltpetre—Cubic Nitre.—This is a salt found already formed in some narrow valleys a short distance from the sea-coast in the provinces of Peru and Chili in South America.

It has in some respects the same effects as Peruvian Guano on the crop in its early growth, but cannot perform all the functions of that manure, inasmuch as it does not contain any Phosphate of Lime or any compound analogous to it.

It however has an advantage over Peruvian Guano in being more efficient when applied as a top dressing, especially when used in the winter or early in the spring.

Nitrate of Soda is a most valuable application to the wheat crop; when it seems slow to start, or when the blades are pale, sickly, yellow or in any manner weak, it gives it a quick growth, turns the leaves green and at once causes them to assume a healthy appearance and greatly increases the product.

It also conduces very much to the brightness in color and strength of the straw. On grass land as a top dressing it is far superior to any other manure that I know of; it greatly increases the product at the time of mowing and keeps the meadows luxuriantly green for a long period afterwards.

I have directed this manure to a meadow as a top dressing mixed with some Mexican Guano, and the product was increased nearly a ton over the part unmanured.

The proper quantity per acre is about fifty pounds, which should be reduced to the finest powder. As a top dressing to wheat it should be applied in conjunction with common salt—about two bushels of salt to fifty pounds of the Chili Saltpetre.

This salt contains an equal quantity of nitrogen or ammoniacal equivalent to No. 1 Peruvian Guano, but it sells at nearly double the price, but it is a remarkable fact, and one which is beneficial to us, that used as a top dressing it equals, indeed exceeds in effect, double the quantity of Peruvian Guano, so that at last it costs no more than Peruvian Guano; very many experiments have shown these results.

These comprise all of the manures hitherto much used for their nitrogen. We have of late several compounds offered to the public to supply this constituent, one of which, from the high character and world-wide fame of its inventor, (Dr. Robert Hare,) demands attention. It is manufactured by treating the flesh and blood of dead animals with Sulphuric acid, and if it does no more than remove the effluvia and miasm produced by decaying animal matter in our large cities, the discovery should be hailed as a blessing. These corporations should well remunerate the distinguished inventor as one who, by this means, contributes so largely to the purification of their atmosphere and preservation of their health. I have not had an opportunity of making an analysis of it, and therefore cannot speak of its precise composition; from the materials employed, however, I am assured it must be a good manure: whether it be a cheap one will depend on the price for which it is sold.

There is another source of nitrogen lately brought to our market, which is a guano sold under the name of Elide Guano, said to be brought from an island in the Gulf of California, near to the Mexican coast. It is a substitute for Peruvian Guano, but should only be sold for about two thirds of the price, provided it corresponds with the sample analyzed by Dr. Chas. Bickell in my office, which analysis is as follows:

No. 29 Exchange Buildings,
Baltimore, Jan. 5th, 1858.

Report of Analysis of a Guano from California—for Wm. Norris, Esq., *of Baltimore City.*

An average sample of the above, which was taken by myself from a lot of 5 bags, now at your warehouse, was analyzed, and found to be composed as follows:

Bone Phosphate of Lime		17.83
containing of Phosphoric Acid, 8.17	11.80	
Bone Phosphate of Magnesia,		6.68
containing of Phosphoric Acid, 3.63		
Alkaline Salts		7.60
Sand, and a trace of Peroxyd of Iron		1.30
Organic matter		34.68
" " capable of producing ammonia, 10.30		
Water		31.91
		100.

Signed C. BICKEL, Ph. D.

When it is remembered that the average of No. 1 Peruvian Guano is about sixteen and a half per cent., and that in this guano we have about ten and a half per cent. of ammonia, and that in the other substances their value is about the same, we can easily calculate what its price should be in comparison with Peruvian Guano. I do not think it likely that there will be much of this guano in market as the locality from whence it comes, does not favor the deposition of ammoniacal guano.

I must here state these general facts to our people, viz: that guano, such as Peruvian or capable of competing with it, cannot be found in places subject to rain, and we should look with great distrust upon those guanos which assume to have a large per centage of ammonia, if they are not found where rain rarely or never falls. The reasons for the above opinion are set forth in the following communication some time since, addressed—

TO HON. I. TOUCEY, *Secretary of the Navy;*

For some time past there have been occasional statements in the newspapers, as to the discovery of an island in the Pacific ocean a few degrees from the Equator, and about fifteen hundred miles from the coast, which would afford a manure equal, if not superior, to that derived from the Chincha Islands, belonging to the Peruvian Government. The existence of this island and its guano deposits, have been so confidently made that not only has a stock company been formed, but the United States Government has sent out a national vessel (the Independence) for the purpose of taking formal possession of it, and thereby furnish to us a guano equal to Peruvian at much less cost. The report made by this vessel on its return was not satisfactory to parties interested, and another expedition has been ordered to take possession of this precious island.

No one would be more gratified than myself if the anticipations as to the existence of this island could be realized, and if a manure could be discovered capable of competing with Peruvian guano; but we should not be deluded with false hopes, nor should our

Government do aught to excite any anticipations which must end in disappointment.

I propose to examine, not the personal testimony upon which the existence of this island is founded, nor even to show the value of the guano said to be found there, if those who are interested in it really give a true sample of it—for this would show it to be inferior to Peruvian guano—but to prove, from indisputable chemico-agricultural facts, and from known meteorological and physical laws, the enunciation, that *if the island does exist, and if it is covered with guano*, THEN THIS GUANO CANNOT BE EQUAL TO THE PERUVIAN BROUGHT FROM THE CHINCHA ISLANDS, AND CANNOT BE A SUBSTITUTE FOR IT.

Let us just state the qualities upon which Peruvian Guano bases its superior efficiency to all others hitherto known—take a view of its composition, and the nature of that which gives it its confessed superiority, show the causes of its peculiarity; and see how far the same state of things can exist in the location where this new island is said to exist. All these things being duly considered and ascertained, it will be seen that *no guano equal to the Peruvian can exist 1500 miles from the western coast of South America.*

First. Peruvian Guano owes its superior efficiency to all other guanos, to the large quantity of ammonia which it is capable of affording by the decomposition of its organic matter. This is now an established axiom in chemistry and in agriculture. It is composed of the excrements of birds containing a large amount of urea, uric acid, and other compounds capable of furnishing ammonia. These different compounds readily decompose when exposed to heat and moisture, produce ammonia, which from its volatile nature, at once passes into the atmosphere—is carried wherever the winds bear it, until brought down by dews or rain. The reason why this decomposition has not taken place in the Peruvian Guano is that on the western coast of South America no rain falls; the deposits made by birds, therefore, lose the water which they naturally contain, by evaporation, and are retained for ages in the condition in which they are exhibited to us in the shape of Peruvian Guano. Now let us state the reasons why no rain falls on these islands, and if the same state of things does not exist in relation to that now being sought by the United States, unless natural laws are reversed or suspended, then rain must fall on it; if it does fall, the guano must suffer decomposition, and consequently be greatly depreciated, and not to be compared to the Peruvian—becoming, indeed, a phosphatic guano, such as the Mexican, or at most only equal to that from the Lobos Islands, which now will not pay for its transportation around the Cape of Good Hope or around Cape Horn.

Rain is the condensation of vapor in the air, by means of cold and from electric causes. The trade winds coming from the coast

of Africa, sweep over the Atlantic, and become saturated with moisture. On reaching the continent of America, this moisture is condensed and falls in the shape of rain, giving supply to the Orinoco, the Amazon and other mighty rivers which pour their flood into the Atlantic Ocean. This wind continuing on its way, sweeps over the summit of the Andes, and is there deprived by extreme cold of all of its vapor—continuing on, it descends the western slopes of the Andes, upon which it finds no water, passes over the narrow space of ocean between the main land and the Chincha Islands too quickly to absorb any *practical* amount of vapor, and therefore can deposit no rain on these islands; consequently, under a tropical sun, the deposits from the birds becomes dry—water being absent, decomposition of organic matter and the escape of ammonia cannot take place, and we have guano on these islands in the same state of purity in which it was deposited there three thousand years ago. This explains the reason of the large per centage of ammoniacal matter in the Chincha Island Guano.

But this condition of Guano cannot exist where there is rain.—Does rain ever fall fifteen hundred miles from the coast of South America, on or near the equator? Known physical and meteorological laws answer yes—direct, positive testimony shows the same thing. Whether the winds at this distance come from the east or the west, the north or south, they will have traversed a sufficient extent of water to have become imbued with moisture, and on any change of temperature the moisture will fall in the shape of rain. Where it does fall decomposition of organic matter must ensue and ammoniacal Guano, such as the Peruvian, *cannot* and *does not* exist. But we are not left to mere natural physical laws to prove this assertion. The Tellifogos Islands are about seven hundred and fifty miles from the coast, there sufficient rain falls to produce vegetation, persons live on them. Take the log book of any vessels sailing through the seas where this island is said to exist, and it will show rain. It rains north of these islands, east and west of it, south of it, all around it, and if not on it, the natural laws are suspended.

There can, therefore, be no reasonable anticipations of finding guano equal to Peruvian in the degrees of latitude and longitude where this island exists, and it will be an useless expenditure of money on the part of the government, and useless exposure of our seamen, to fit out and dispatch such an expedition. If the government wishes to really benefit (as it does) our agricultural interests, let several small vessels be sent through the Gulf of Mexico and the Caribbean sea, and take possession of all islands not belonging to other nations, and reserve them for the use of the United States; many of these islands contain valuable deposits of phosphate—i. e. guanos, such as Mexican and Columbian, which would prove of great benefit not only to our agricultural, but also to our commercial interest. This I advised to the Navy Department in the year

1852, and hope now that expeditions of this sort will be undertaken, instead of the long, expensive and useless one to the Pacific ocean.

Specimens of the guano found on this island were sent to the Patent Office for distribution. It was analyzed at my office, and only there, and found to contain but a very small amount of ammonia. It was a phosphatic guano like the Mexican.

These are the principal manures which afford nitrogen to plants, they are expensive, liable to loss by improper or careless management, and are most efficient in the production of crops, this should teach us the most cautious behaviour in relation to their purchase, and, when purchased, their most careful subsequent treatment and application. On these several points I have given all requisite information to the Planter and Farmer.

The rules which I have laid down for each and the directions given, are educed from the observations and experience of a large number of our most reliable practical agriculturalists, from scientific deductions, from the nature and composition of the articles spoken of, and it is advice necessary for the protection of all tillers of the soil, which they should follow.

Phosphatic Manures.

The manures which supply Phosphoric acid to plants, are Bone Dust, Superphosphate o Lime, and various guanos under various names, brought to our markets from islands in the Gulf of Mexico and the Caribbean Sea.

We shall in the first place speak of Bone Dust and the manures made from it.

Bone Dust—Phosphate of Lime—Superphosphate—Biphosphate or Dissolved Bones.—The necessity of the chief elements of bones, phosphoric acid and lime, to the production of crops needs no proof, whether we examine the constituents of fertile soils, the crops cultivated for the support of men and animals, or the composition of men and animals themselves, which is derived from food furnished by crops. In the present article I shall confine myself to the preparation and best mode of application of the phosphates, uniting as much brevity as possible, with explanations full enough for the good understanding of the subject.

The bones of all animals are composed mainly of phosphoric acid and lime, forming what is called bone phosphate of lime; besides these they contain a small proportion of phosphoric acid, in union with magnesia, (phosphate of magnesia,) carbonate of lime, soda and potash; the two last, and several other substances in very small proportions, of no practical value here—these ar the minera

constituents. But bones contain, when fresh, from 40 to 50 per cent. of organic matter, which is capable of affording about six per cent. of ammonia by its decomposition. Bone dust as sold in the market usually contains from 60 to 70 per cent. of phosphate of lime. The drying, boiling and sometimes burning of the bones renders the quantity of mineral matter comparatively greater than is found in fresh bones. Besides in bones, combinations of phosphoric acid are found in wood ashes, in guanos, in poudrette, and in very small quantities in some marls and limestones. To supply phosphates we should either look to bones, to Mexican or other phosphatic guanos.

Mode of Application.—The manner and form in which a manure is applied is frequently of as much importance as the manure itself. Bone dust is comparatively of high cost, and very often the form in which it may be applied is of great consequence. Bone dust should never be applied except in the finest powder, or dissolved in sulphuric acid, and forming the well known superphosphate of Lime. True economy, which is the judicious application of means, requires that it should always be dissolved before using it.

In agriculture we have to deal with two varieties of the phosphate of lime; one, the bone earth phosphate or bone dust, in its natural form; the other, the acid phosphate of lime, superphosphate, or biphosphate. One of the greatest boons which science has conferred on agriculture is that of dissolving bones before using them. In the condition in which bones originally exist, and even when they are ground to the finest powder, they are still comparatively insoluble, and we must apply a large quantity to supply the growing crop. When dissolved by means of sulphuric acid they are then very soluble, can be spread much more equally over the soil, and will exert a much speedier influence on the crop. It is not out of place here to speak of some of the more important changes which take place on the addition of sulphuric acid to bone dust or phosphate of lime. Pure neutral phosphate of lime contains of

Phosphoric acid,..	48.50 per cent.
Lime, ...	51.50 per cent.

Biphosphate of lime is composed of

Phosphoric acid,..	71.50 per cent.
Lime,...	28.50 per cent.

This latter compound is very soluble aud is produced in this way. In chemistry we have what are called weak and strong acids. When a weak acid is united to a base, a stronger acid will expel it and seize on the base itself. We have a familiar example

of this in the mixing of soda powders where tartaric acid is mixed with carbonate of soda; here the tartaric acid, being the stronger, expels the carbonic acid and unites to the soda, the carbonic acid causing effervescence as it escapes. When sulphuric acid is added to bones it drives a part of the phosphoric acid from their lime and unites to it, forming sulphate of lime, (gypsum, or plaster of Paris.) The phosphoric acid thus set free does not escape, as would carbonic acid, but either unites to a smaller proportion of lime, or is left alone in solution, according to the quantity of sulphuric acid employed. To convert 100 parts of pure phosphate of lime into the biphosphate, 45 parts of absolute or pure sulphuric acid must be added; we then shall have about 68 parts of biphosphate of lime and 77 parts of sulphate of lime or gypsum, and we have in the mixture biphosphate and sulphate of lime mixed mechanically together.

When this compound is added to the soil, from its extreme solubility it is carried to every part of it, and there meeting with lime or other bases it is reconverted into the neutral phosphate again, or if it meets with potash or soda into the phosphate of these bases. So, although it may eventually be restored to the same compound, nevertheless a most important and vital point has been gained. When dissolved, it has entered into every pore in the soil, has come in contact with every particle of earth, and has become most intimately blended with the earth to be cultivated; so that from its minute subdivision, every point in the soil can furnish to the plant this material for its support; for other things being equal, the solubility of bodies is in proportion to the fineness of their divisions, and all manures must be dissolved before they can act on vegetation. It becomes then a matter of great interest to the consumer to have his bone dust not only dissolved, but to have it treated afterwards with such substances as will not reproduce the original compound, if lime be employed, this will take place, and though we may have bones reduced to a very fine state of division, yet we have to rely on mechanical means to mix them with the soil instead of the thorough and complete mixture which takes place when they are applied in a soluble state, and thus reach every atom of the soil.—This is a point of the highest importance and should always be *strictly* attended to.

Mode of Treatment and Quantity of Acid to be used.—Without going into the reasons and showing the calculations from which they were formed, I will here state that for every hundred pounds of bones to be acted on, about thirty-three pounds of sulphuric acid of specific gravity of 1.70 should be used; of course the quantity of commercial acid is to be increased when it is of less specific gravity. The bones should be finely ground and then moistened with water, after which the acid should be gradually added, and the mass thoroughly stirred. This is important to be attended to,

as otherwise a coating of sulphate of lime will form over the particles of bones and prevent the further action of the acid. They should be suffered to stand for ten days or a fortnight, be very frequently stirred, and then their superfluous moisture dried with saw dust, wheat chaff or any convenient substance except lime, for the reasons before given.

The handling of the sulphuric acid requires caution, as it will excoriate the skin or burn the clothes of those who handle it if it comes in contact with them. The best mode is to have a bent leaden tube or siphon, with a stop-cock at one end; this should be filled with water, the short end placed in the sulphuric acid, the long one with the stop-cock over the bones; the stop cock is now to be turned, and the acid can in this manner be applied without any risk or danger to those using it.

Quantity and Cost per Acre.—The proper quantity of dissolved bones, as near as I can know from all the information which I have upon the subject, is about five bushels to be sown broadcast at the time of sowing or planting the crops. The cost, exclusive of labor, which is but slight, will be of

Bones, 5 bushels, 250 lbs., at 50 cents per bushel,.	$2 50
Sulphuric acid, 83 lbs., 2½ cents per lb.,..................	2 07½
	$4 57½

Or at most five dollars per acre. This will in every instance, if judiciously applied, produce an increase, equal to the above sum in every crop for four or five years, and then leave the land much better than before its application. To those who are in the habit of manuring fields with stable manure, this quantity added will enable them to dispense with an amount of stable manure double in price to the above, make its action more permanent and produce better crops. It should in every instance be thoroughly mixed with the manure before being applied. I offer this suggestion particularly to those who have market farms in the neighborhood of our cities, and to whom the cost alone of hauling stable manure is very great.

Farmers should take every occasion to manufacture their own manures, as they have had no certainty of the purity of the articles bought, and therefore have heretofore incurred great loss. I have shown, when speaking of guano, how this has been the case in relation to this article; and if so in this, how much more likely is it to be the case in a manufactured article, where no check exists to prevent its adulteration or impurity, and which few have the ability to detect? The value of dissolved bones depends on their phosphate of lime being converted into biphosphate of lime; and to show how important this is, it is

enough to recollect that whilst the former is not worth more than 1½ cents, whilst the latter is worth from 8 to 9 cents per pound.

The loss likely to be sustained by purchasers of an inferior article is sufficiently manifest, when it is considered that that inferiority may result from the ignorance as well as the dishonesty of the manufacturer, and in both of these qualities we have no reason to doubt their deficiency. By manufacturing for themselves, the consumers will escape loss from either cause. The points here in reference to which I wish to call particular attention of the agriculturists, are:

1. That bones should be used in their most soluble form—that is, dissolved in sulphuric acid, as above directed.

2. In preparing the mixture the bones should be as fine as possible.

3. That the quality of the sulphuric acid employed should be well ascertained and paid for accordingly.

4. That lime, or substances containing much of this, should not be used to dry the mixture.

5. That they may be employed with benefit either at the time of sowing wheat or planting corn, or may be used as a top dressing to wheat in the spring; and

6. That the purchaser should well ascertain the composition of this manure when bought, as it may and does vary from many causes.

To within a few years past bone dust and superphosphate of lime made from it or from (coprolites) the fæces of antediluvian animals, were the only sources for the supply of phosphoric acid or phosphate of lime. Since then a large quantity of Guano from islands in the Gulf of Mexico and the Caribbean sea, and the waters adjoining these, have been imported here under the names of Mexican, Columbian, Sombrero, Nevosa, and other guanos.

These differ much from each other in their per centage of phosphate of lime, and differ very much from themselves in different cargoes. From the variety of their composition it is impossible to lay down any rules for their purchase in order to avoid impositions, or for the quantity to be applied per acre. In order to supply the proper quantity of phosphoric, there is one special one, however, which should never be neglected, and that is to buy it from a person of known integrity who has no interest in selling a bad article, and one who has had made for him an analysis by a competent analytical chemist, not a pretender, and then have the article bought guaranteed to be of the same composition as the article sold. They should not buy it from the recommendations or puffs in venal newspapers, nor from the inspection marks, as these cannot be relied on to show the composition

of the Guano with sufficient accuracy to protect the planter and farmer.

There is another article under the name of "El Roque Guano," which is not entitled to the name of Guano, it being a mineral product and not the excrement of birds or other animals, it is not a phosphate of lime such as is found in Bones, Mexican and Columbian Guano, but a phosphate of iron and alumina, somewhat similar in composition to the deposits of blue earth found in the neighborhood of Still Pond, in Kent County, in Worcester County, on the farms of Dr. Watkins, J. T. Hodges, Esq., Hon. J. S. Sellman in A. A. Co., and on the farms of J. Mulliken, Mr. Berry and others in Prince George's County; and is worth no more than the said blue earth, (vivianite,) when existing in a state of purity; farmers will not be induced by its name to purchase it, for it is a fase one. Unless the above advice is followed they are constantly liable to the grossest imposition in the purchase of Mexican, Columbian and other phosphatic guanos, more so in these than in Peruvian, the former are brought here by various individuals, few of whom know the difference between a good and a bad article, and the knowledge on the part of the purchaser is not increased by the inspection laws, as I shall show when making some recommendations as to their revision.

The proper quantity of phosphate of lime per acre is that contained in about five bushels of bone dust, two hundred and fifty pounds of phosphatic guano, which should contain about fifty per cent. of phosphate of lime or about two hundred pounds of a *veritable* superphosphate of lime. These are not exactly equivalent numbers, but sufficiently near so for practical purposes.

Mode of Application—Soils and Crops to which it should be applied.—The best mode of application in order to receive the full benefit of phosphate of lime in the form of bone dust, or the phosphatic guanos, is to apply it broad-cast at the time of sowing wheat, or to the land when it is prepared for the planting of corn, tobacco, cabbage, &c. Manures of this class are not so immediately forcing as Peruvian Guano, but they act on the plant at a later period of its growth, whilst the leaves, stalk and grains are in the process of formation. At this time the roots of the plants have entered far and wide into the ground, and the phosphate of lime should be equally diffused through the land in order to be taken up by them and introduced in the body of the plant. This diffusion cannot take place but to a very limited extent when phosphatic manures are put in the hill or used with a drill.

It is frequently very expedient to apply these manures to the same soil and crop with Peruvian Guano, the best quantities are from seventy-five to one hundred pounds of Peruvian with from one hundred and fifty to two hundred pounds of phosphatic guano containing about fifty per cent. of phosphate of lime. The phosphatic manure should be applied broad-cast and the Peruvian Guano be applied with a drill in the case of wheat, or mixed with wood earth, and in the hill with corn, tobacco, cabbage, &c.

The equal mixture of large quantities of substances is very difficult, and indeed useless when done in the case of the guanos before being applied to the soil. If, however, Farmers and Planters prefer such an admixture, they should in EVERY INSTANCE DO IT FOR THEMSELVES, and not buy the mixture from others. The guanos can easily be reduced to very fine powder by means of the corn and cob crushing mills now sold, and by the same means as thoroughly mixed as can be done by other means used by manufacturers and venders. After the grinding of the guano, the mill can then be easily cleansed for use by running a few corn shucks and corn cobs through it. I have frequently seen guano prepared in this way in first rate style, and have heard the most favorable reports as to its efficiency from many sound practical farmers.

Phosphatic guanos should be applied to crops which have a broad leafy development, as this class of plants can more readily obtain nutriment from the air of the kind furnished by Peruvian guano, than those which have narrow leaves.

The above rules apply with equal force to the Superphosphate of Lime, of which large quantities are being used, especially for corn and tobacco.

The indications for the use of this class of manures, is the absence of a proper quantity of Phosphate of Lime in the soil, and in a form so that the growing plant cannot assimilate it.

There is no manure, which in its use, shows more clearly and distinctly, the intimate connection which should exist between analytical chemistry and practical agriculture than this, and how either, without the aid of the other, is liable to error. In the anslysis of a soil by the most approved means, sometimes there is shown a quantity of Phosphate of Lime sufficient for crops for a series of years, and yet on this soil, Phosphate of Lime may frequently greatly increase the quantity of the crop. This seeming contradiction can be most truly explained by the fact that, the Phosphate of Lime is so associated with other minerals of an insoluble nature, *as not to be available in proper quantities for plants,*

and at the time when they most need them. On soils of this nature, proper means should be used for the disintegration of the soil. These are the use of Lime and the turning in of green crops, the suffering of them to lie on the surface or heavy dressings of coarse straw and litter. These will decompose the inert minerals, of the soil, liberate its Phosphate of Lime, and be equivalent in effects to an application of this substance, as it brings it forward in an available form. Practice, in adopting general rules from the above, would greatly err in adding annually on such soils costly Phosphate of Lime, instead of the cheaper and more permanent manures for its disintegration. There are other soils on which Phosphate of Lime would act well, because it does not exist in them in any form. On these it must be annually applied, no cultivation and no other manure can be a substitute for it. In the one case, practice teaches that Phosphate of Lime is *for the present* a good application, but science teaches practice, on the other, how to dispense with it by substituting cheaper manure, and how for the Phosphate of Lime in the latter case, there can be no substitute.

There are thousands of acres of both of these descriptions of land in Maryland.

Calcareous Manures.

Under this term we include such substances as are used in agriculture, for the effects of the lime and magnesia which they contain.

The sources of lime are very various. There are common limestone, magnesian limestone, shell marl, pure marl, the skeletons of various shell-fish, the chief of which are oysters, shell sand &c., &c. Substances containing lime as a characteristic ingredient, are called calcareous from the Latin word, Calx, which signifies lime.

We will now give the nature, composition, history, uses and abuses of lime, in agriculture. These last would make a paper as long as the former; for it has been so often employed empirically without success—so frequently used without benefit, that its virtues have been obscured by the vices which surround it. It is like other strong agents, powerful forgood or evil, as it is wisely or improvidently used, and beneficial or destructive, according to the correctness of the principles which dictated its special application.

Lime naturally exists most generally in combination with carbonic acid, where it forms the various kinds of limestone, marble

and marl. In this condition, it forms a large extent of the solid structure of our globe as limestones of different degrees of purity; it is sometimes associated with magnesia, and this is then called Dolomite, from the name of Dolomieu, who first described it; sometimes we also have with it, in a visible form, mica; and here I must caution those who are but slightly acquainted with chemistry, not to condemn limestones as worthless, which have a large residue after being treated with muriatic or any strong acid. This residue is frequently mica, which contains potash, more valuable by far, than the part soluble in acid. Pure, quick unslaked lime is not an element, but a compound formed of oxygen, a gas, and calcium, a metal; it is therefore the oxyd or rust of a metal; with carbonic acid it becomes the common air-slaked lime; with water it is the hydrate of lime, or water-slaked lime. The quantity of pure lime (oxyd of calcium) in air-slaked lime, is 56 29 per cent.; in water-slaked lime, the quantity of pure lime is about 76 per cent. As lime is that which we wish to buy in lime, its value depends on the quantity of pure lime, or oxyd of calcium in the article which we purchase, and any one can, by the Rule of Three, calculate the quantity of pure lime in air or water-slaked lime, from the above statement. Lime has many appliances, but we shall alone consider it in its references to agriculture.

The history of the use of lime is interesting in many particulars, in none more so than as it affords a convincing proof in itself of the incompetency of experience alone to determine the conditions on which a manure should be used. If the world could, by long acquaintance with and frequent use of a substance, understand the principles which should dictate its employment, lime would have been the agent by which it would have been taught; for no other manure has been used so long, none so extensively, and none with such diverse effects.

Even before the Christian era, Pliny tells us that "Edui et Pictoues agros calce uberrimos fecit"—that the Edui and Picts made their fields very rich by means of lime. Marl was used in great abundance, before the discovery of our country. In the reign of Edward I. and II. of England, the leases have conditions that the tenant should use a particular quantity of marl. In the Forest Charters, as early as the year 1200 A. D., persons were forbidden, unless with certain precautions, to dig marl pits near to the king's highway.

These facts show that the use of burnt lime and marl was well known and practiced long before this time, and well would it have been for succeeding generations, had the composition of the soil, the exact composition of the lime, and marl been known. Had there been recorded facts attendant upon its use—had science raised the veil which covered its mode of action and the philosophy of its use, there would have been no proverb in Scotland, that

"lime enriches the father but impoverishes the son." The fact would have been, that lime, whenever employed, would have not only enriched the father, but the son also. Let the conditions become known on which its profitable employment depends, its use would be then only in similar conditions, and profits would always be the result. How many men now in our own state, wise men, acute men, practical men, who have employed lime without one cent of benefit, might have been at least saved their expense, had they consulted some other rule than that given by its successful employment by another on a different soil. Many persons employ lime merely because somebody else has done so with benefit, whilst if a survey had been made of all the facts, reasons sufficient for a contrary practice would have been obtained. The many and various recommendations when, where and how to use this manure, are so many concessions of the ignorance of one general catholic truth. Had a true theory of vegetable physiology, and a true knowledge of analytical chemistry been employed, then the principles of the application of lime and all other manures, would have dictated their use only where properly required. There not being this knowledge, speculation wild and vague, because it had no bounds of control, took the place of true philosophy, and the reasons given for the use of lime were as many as the places in which it was used.

Error, however always yields in form at least to truth, and the necessity for a knowledge of the nature and character of the soil, was conceded by speaking of the adaptation of lime to stiff clays and light clays, to loamy clays and clayey loams, sandy loams and loamy sands, to stiff and light clays. These terms are all so many definitions—short descriptions of the composition of the soil; and if any description of a soil is of value to indicate the propriety of the employment of a manure, that is best which is the most thorough and comprehensive.

In the classification which has been given of manures, it will be seen that lime not only acts by affording itself as material for various parts of the plant, but that it also causes substances which may be present in a soil in an insoluble condition to assume a soluble form; it also decomposes the vegetable matter in a soil. Lime, therefore, has a wide range of efficacy, and the indications for its use are equally extensive.

1. Whenever a soil is so deficient in lime as not to have a sufficiency to give a skeleton to the plant.

2. Whenever a soil contains minerals insoluble to ordinary agencies, which contain any of the inorganic matter necessary for the food of plants.

Whenever it contains a large quantity of undecomposed organic (vegetable) matter, then lime should be used. These are the only occasions on which it should ever be employed.

3. The quantity of lime adequate to the first purpose, that of giving, per se, food to the plant—is very small. I have repeatedly examined soils with as little as one-tenth of one per cent. of lime, capable of producing ten barrels of Indian corn (maize) to the acre.

The minerals most generally present, which require the presence of quick lime for their degradation, and for their solubility, are mica, (isinglass,) felspar and hornblende—they are those which are present in all granite soils. The red sub-soil clays, so abundant in many parts of our state, are formed from those rocks, and to them, when unproductive, quick or water slaked lime will always be beneficial.

The agency of lime in decomposing vegetable matter, is also, not an unimportant function, Some limestones contain small quantities of sulphate of lime, (gypsum,) and phosphate of lime, (bone-earth,) and also potash. The value of a limesone is materially increased to a soil not containing felspar, mica or hornblendes, when it contains mica as one of its constituents, as these soils are most generally deficient in potash, which these minerals supply.

Lime existing in shells and limestones, naturally, in the form of carbonate, is deprived of its carbonic acid, by being burnt in kilns. When exposed to the atmosphere it again receives its carbonic acid, and thus becomes *air-slaked*, and crumbles into fine powder.—When water is added to quick lime it generates a large quantity of heat, unites to a definite quantity of water, and becomes *water-slaked*, still retaining, however, some of its caustic properties. These are entirely destroyed when it is air slaked.

The limestones of our state vary very much in their constituents, even when of the same formation, and lying very close to each other.

There will be seen from what has been said above, that many limestones are Dolomites—that is, composed of a large quantity of magnesia.

Magnesia, like lime, is the oxyd or rust of a metal, called magnesium, which never exists in its pure state. Magnesia exists as carbonate---that is, as air-slaked magnesia, in rocks, and when exposed to a sufficient degree of heat, in kilns, loses its carbonic acid, and then becomes quick, caustic, or what it is most usually called, *calcined* magnesia. This, on exposure to the air, absorbs carbonic acid from it, and becomes again *mild*, or carbonate of magnesia: it however does this very slowly, and remains caustic a much longer time than lime. It also unites to water, in definite proportions, but not with the same intensity of action as lime, and gives out but little heat, in consequence of the slowness with which the union is formed between it and water.

In Dolomites, or magnesian limestones, the proportions of lime and magnesia are very variable, as "isomorphous substances crys-

tallize together in all proportions." The precise quantity of magnesia can only be determined by chemical analyses of the stone.

There has been a long and wide-spread prejudice against the use of this substance in agriculture; opinions adverse to its use have been promulgated by ancient writers on the subject of agriculture; those have been taken up and adopted by others, without examination, until, to urge the use of magnesian lime was a heresy unheard of in the annals of agriculture. As long as men had opinions not founded on reason and investigation, and so long as they did not possess the means of investigation, they were entitled to charity for their errors; but those who now commit them, can give no such palliation for their commission. When the examination of the ashes of plants showed always a large per centage of magnesia, common sense would seem to show that, inasmuch as this magnesia could only be derived from the soil, that it should be applied when wanting or deficient in the soil.

On the soils not containing a large quantity of vegetable matter, from twenty to forty bushels of magnesian lime to the acre is the best quantity. This quantity should be applied every three or four years, until about two hundred bushels shall have been used. The larger the per centage of magnesia in the lime, the smaller the quantity to be used.

The proper quantity of lime per acre is a question, the solution of which is attended with great difficulty. To arrive at as correct conclusions as possible, I have examined very many productive soils, and if their fertility depended solely on lime,—if it was the only element to enter into the calculation, we might very readily solve the question. But the fertility of a soil does not depend upon the quantity, of any one constituent, but upon the proper proportion of them, and also upon the mechanical texture of the soil. To arrive at conclusions, then, we must not only have examined very many different soils of known fertility, but also be cognizant of the action of different quantities of lime upon soils of known composition.

The proper quantity, too, varies upon different soils, some requiring a much larger quantity than others, whilst to many lands it is entirely useless. The proper quantity depends—

1st. On the quantity of insoluble mineral matters in the soil.

2d. The quantity of undecomposed vegetable matter. The mechanical properties of the soil, when that is the only fault, can be more cheaply improved by other means than lime.

Shell banks are another source from which lime is supplied to soils in the tide-water counties of our State.

These shell banks are deposits of oyster shells made by the aborigines of our country, and sometimes cover an area of forty acres, in any places to the depth of six or eight feet.

From long exposure to atmospheric influence, and other causes, the shells have become disintegrated, and readily crumble on free exposure to the air. Again, after the lapse of a considerable period, they become very much disorganized by another process. At first a little moss forms on the surface of the shells; this takes up enough lime that has been dissolved by the carbonic acid of the atmosphere to give support to a higher order of vegetation. This vegetation, by its decay, furnishes food for a succeeding generation of plants, and by an increased supply of carbonic acid dissolves more lime to supply another generation. This, in its turn, dying, furnishes increased means for the solution of the shell, until in many cases these banks are covered with the most luxuriant vegetation, and support large trees. The layer of matter covering the shells is called "shell mould," and consists of shells in a very comminuted state, and the organic and inorganic remains of the plants to which it owes its formation. A little reflection will at once show, that this mould must prove a most valuable manure, being nothing but the remains, the ashes, so to speak, of plants, mixed with a large quantity of oyster shells, in a very minute state of division.

This mould contains of air-slaked lime, by the average of 25 different analyses, about 45 6 per cent. being more than half as good as common agricultural lime; and when we also consider the other matters in this mould, the ratio to limestone is much increased. It is almost needless to say that the lime in this *mould* is identical with that in limestones, fresh shells, &c., and will act equally as well. A custom has prevailed, to a very injurious extent, of applying the mould together with quantities of large, coarse fragments of shells. I cannot too strongly reprobate this mode of using the banks. These large fragments take up much space in the soil that should be filled by other matter, injure its texture, and render the crops grown on it very liable to *burn* or *fire*. Though these shells be composed of lime, it is not available, but in a very slight degree, to the use of crops. Lime, to be serviceable, must be in the state of very fine powder, and intimately incorporated with the soil. When it exists in shells of any size, it does almost no good by its presence, and, as I have before said, *injures* the texture of the soil. For all present practical purposes, pebble stones would be equally beneficial.

The best way to use these shell banks is to have a sieve fixed with a slight inclination. Against this the shells should be thrown, as when persons wish to free sand from gravel. The fine particles which pass through the sive should be applied as they are, whilst the coarse shells which do not pass through, should be put into kilns and burnt. In this way no part of these valuable deposits would be lost; all would be saved for agricultural improvement, thereby increasing the quantity of crops, and augmenting the value of land, instead of retarding its improvement, as is the case when

coarse shells are applied. The lime from these old shells is equally as valuable as that derived from those which are recent. Some of the best crops, and the finest land, have been produced *solely* by the application of shell mould and lime burnt from shell banks.

Mode and Condition in which Lime should be Applied.—A knowledge of the specific action and effect of lime affords us the clearest and only rational explanation on this subject.

We have elsewhere stated that lime acts chiefly by decomposing the insoluble minerals in a soil, and thus causes them to assume a form in which their constituents can be used by plants; that it decomposes inert vegetable matter, and causes it to give its dormant materials to the plant; that it affords in itself material for the structure of the plant. It also acts by changing and correcting the physical properties of soils.

Since one of the effects of lime on the soil is the decomposition of mineral and vegetable matter, the first inquiry naturally is, in what condition will it best effect this purpose; for in that condition of course, if possible, it should be applied. Does lime best decompose mineral and vegetable substances when it is in the condition of *carbonate or air-slaked lime*, *hydrate or water-slaked lime*, or *quick or caustic lime?*

The experience of every one who has any knowledge or experience on the subject, shows, and the opinion of every one acquainted with the nature and the properties of lime, and of mineral and vegetable matter, is, that lime, when quick or caustic, acts more vigorously than either water-slaked or air-slaked lime.

It is also well ascertained that water-slaked lime, though not quite so efficient as quick or caustic lime, nevertheless, exercises a much more potent influence in decomposing mineral and vegetable matter, than does air-slaked lime, which only acts so in a very slight degree.

The conclusion, then, from these premises, which are true, is, that lime should always be applied either in the quick or caustic state, or as water-slaked lime to soils having insoluble minerals, and that it should never be suffered to slake in the air before being used; because just in proportion to its degree of air-slaking, is its virtue destroyed and its power lost, to produce its desired effects.

If *possible*, lime should then always be applied in the caustic state to soils of this class; when this cannot be done, then it should be used as water-slaked lime, and in this condition it can always be applied.

The practice which is frequently followed of hauling out lime from the kiln and letting it lie in heaps months before scattering it, is fraught with great expense in the loss of the specific effects of lime—a part, and a large part of it becomes air-slaked, and is thus for ever deprived of any power to benefit the land. The whole effect of lime, when used in this way, is due to that part which be-

comes water-slaked by rains and dew. *The air-slaked part is utterly and for ever lost on soils having in them undecomposed minerals.*

There is another objection, too, and a very strong one, to the use of lime in this way. By continued exposure in heaps it frequently runs together, and becomes cemented into lumps, so that much of it is lost—it cannot be evenly distributed—some places get too much, some too little.

I call the attention of persons who have been using or intend to use lime in this way, to the facts which I have given above in relation to the effects of lime, and feel sure that with due reflection they will coincide in my views, and act accordingly.

Lime, then, should always be used as quick lime or as water-slaked lime, unless on particular soils, the localities of which have been given to the people of the State.

The best time to use it is in the fallow land where it is freshly ploughed for a spring crop for corn, and it should be scattered as evenly as possible over the surface, and then harrowed with a heavy harrow, in order to mix it as completely as possible with the soil. When land is first ploughed for wheat, it then can also be applied to the surface—the subsequent ploughing to get the land in order for this crop, will mix it well with the soil. It can also be profitably employed before planting the corn crop, as in the spring repeated workings of the soil will always mix it well, and produce its full effect. The reason why I particularly urge the application and turning in of lime in the fall is, that then the decomposition of vegetable matter, is to a great extent suspended, and the lime is not so quickly converted into carbonate or air-slaked lime, but retains its power and exercises it to the fullest extent in acting on the comparatively insoluble minerals in the soil.

It should never be applied to the surface and suffered to remain there any length of time before being turned in, as a large quantity, dependent on the length of time that it is thus exposed, is lost on granite soils and others of this class.

Besides the sources of lime mentioned above, there is another —that from the refuse of Gas Light manufacture, known in common, and described in my former Reports, as "Gas House Lime." The following is the composition of the Gas House Lime sold in the city of Baltimore; this analysis, however, does not represent the composition of Gas House Lime made in other places from other coal, as the quantity of sulphur compounds in this lime will vary in exact proportion to the amount of sulphur in the coal from which the Gas is manufactured, and its composition cannot be ascertained unless by analysis.

The following is an analysis and report of the Gas House Lime sold in Baltimore, and delivered on board of vessels at any wharf for five cents per bushel. The analysis of a sample of Gas House Lime shows its composition to be as follows:

Per centage Composition of Baltimore Gas House Lime.

Hydrate of Lime, (water-slacked lime,)	41.17
Hydrate of Magnesia	1.02
Carbonate of Lime, (air-slacked lime,)	28.48
Hydrated Sulphate of Lime, (plaster of Paris,)	4.93
Hydrosulphate of sulphuret of calcium	3.79
Hydrosulphate of sulphuret of Iron	4.67
containing of sulphureted hydrogen 5.03.	
Phosphate of Lime, (bone-earth,)	0.26
Sand	2.94
Water	12.74
	100.

By reference to my first Report to the House of Delegates of Maryland, you will perceive that I then published the result of several examinations of this lime, and recommended its use under certain conditions. Since then I have carefully watched its effects and collected all the facts attending its application, and am confirmed in the belief, that not only is this lime free from injurious effects, when properly used, but that on certain soils it is preferable to every other variety of lime. *It can be properly used wherever oyster shell lime or stone lime, free from magnesia, is indicated.*

The mode in which this lime should be applied, depends on the peculiar properties resulting from its composition, which is constantly changing on account of the presence of the hydrosulphates of lime and iron in it. These substances cannot long exist under the influence of atmospheric air, and are finally converted into lime (plaster of Paris) and peroxyd of iron. The quantity of sulphate of lime which is contained in this article, indicates to what extent this process of decomposition has already advanced, and which, of course, will be quickened when the lime is scattered and exposed to the full influence of the atmosphere. Besides these substances, we meet with a large per centage of water-slacked lime, which also undergoes a change under the influence of the atmosphere, being converted into air-slacked lime. 100 parts of this lime will therefore eventually become converted into 72.87 parts of air-slacked lime, and 30.13 parts of plaster of Paris; the other substances as given in the analysis remain unchanged.

Mode of Application.—This lime should therefore be applied to the surface in the fall, suffered to remain there, and then turned in in the spring, for any summer crop; or it may be applied on the surface in the spring, and turned in in the fall, for a wheat or any other winter crop. In this way no possible damage could happen from its use; on the contrary, reliable gentlemen have in-

formed me that they have experienced most excellent effects from it when used in this way, many of which I have witnessed.—There is another valuable effect of this lime not possessed by any other, which is its tendency to destroy insects.

I have been informed of many applications of gas lime, always with beneficial effects when applied properly. The supply of it in our market does not more than meet the demand.

Shell Marl is another most fruitful source for the application of lime to soils, and moreover a most valuable one. In my previous Reports to the House of Delegates, I have spoken very fully of its best mode of application, the quantity to be used and indeed every thing of practical value connected with it The analyses of many marls not published in my Reports have been given to the interested, to the whole people of the State, I omit their republication. For much of my advice I have been indebted to information given personally by, and from the printed publications of the Hon. Edmund Ruffin, of Va., whose works on the subject of Calcareous Manures, especially marl, contain more valuable original truths than any one, or all written on these subjects. Persons living in the tide water districts of our country, will find them to be most valuable sources of information.

Miscellaneous Manures.

Gypsum—Common Salt.—We comprise these two manures under one head; not that they are similar either in their composition or mode of action, but because there is no very appropriate class to which they can be referred; and they act more as *mediums* than as direct nutriments.

Gypsum in its pure state is composed as follows:

Lime	33	per cent.
Sulphuric acid	46	"
Water	21	"

Experience has determined that the crops on which it should be used are those only which have a large leafy surface, such as clover, beans, peas cabbage and tobacco, and is best applied to clover, peas, beans, cabbage and tobacco when their leaves first begin to expand; on corn it should be used just when the *silk* begins to form. On wheat, timothy, oats, &c., its beneficial action is not so clearly manifest as on the crops which I first mentioned.

Very much has been said with regard to the theory, i. e., the philosophical explanation of the way, or *ways*, in which plaster acts. On this subject I can but say that the beneficial influence of plaster on broad leaf plants must be explained in some other

way than that of its affording them *direct* nourishment by the assimilation of its constituent parts.

Sulphuric acid is, as a *direct nutriment*, less essential to clover and others of its class on which it best acts, than to other classes of our cultivated plants, as they contain the smallest amount of compounds united to sulphuric acid, and also less of sulphur; as to the influence of its other constituent, lime, it is present as a *nutriment* in sufficient abundance in nearly every soil, and moreover, plaster acts well, and sometimes best, on those soils which have been heavily limed or which originally contain the largest amount of calcareous matter, its beneficial action must therefore be explained by the relations which it bears to ammonia. It is certainly known that plaster of Paris *when dissolved* exercises an attractive influence on carbonate of ammonia, and by a transposition of its elements fixes it, by forming sulphate of ammonia. This action is however reversed in the dry state, for a mixture of sulphate of ammonia and carbonate of lime will evolve carbonate of ammonia.

Now clover and the other crops which I have mentioned are famous for the large extent of their leafy surface, and derive most of their *nitrogen by assimilating it through their leaves*, leaving the soil richer in this substance than before these crops were produced. Clover and all the plants of this class therefore obtain most of their organic nutriment through their leaves. Plaster, therefore, being sown on these leaves, and the weather being moist or dew being in sufficient quantity to dissolve it, will at once *fix* the ammonia of the atmosphere, and the leaves will take it up and carry it throughout the whole organization of the plant.

This view of the action of the plaster is strengthened by the known facts in relation to its utility. If plowed in the soil, it never produces the same effect as when sown broad-cast. It does not act so well on plants which have but a small leafy surface as on those which have that surface very extended. It has no action in dry, windy weather. It does not act when mixed in the soil on moist land, which shows that its want of action in dry, windy weather is not due alone to its not being dissolved.

Furthermore, and I deem this conclusive as to the views which I have given above; soils may contain a sufficiency of plaster to meet all the wants of the crop, and yet the particular class of plants which I have above enumerated will be much benefited in particular seasons by having plaster sown broad-cast over them.

When sown broad-cast it adheres to the surface of the leaves, and being dissolved by dew it fixes the volatile carbonate of ammonia of the atmosphere, which is taken up by the leaves, and this explains fully all the phenomena of its beneficial action.—

This, though a novel, yet I think is a correct explanation, at least it more thoroughly explains the well known facts attending the action of this substance than any other view which I have seen taken of it.

Common Salt.—The *mode* of action of this substance is uncertain as yet, but experience has shown that it is a very useful application on all soils that have a tendency to produce crops of wheat liable to be *straw-fallen.* It gives a clean, strong straw, *increases the weight of the grain*, and imparts such vigor to the crops on which it should be used as to render them much more free from loss by attacks from insects or by unfavorable weather, than otherwise they would be. It also acts as a manure by dissolving the phosphate of lime which may exist in the soil, and thus rendering it available to plants. *It should be applied in the latter part of winter or early in the spring, when the wheat crop first begins its growth after the cold weather.*

The quantity to be applied annually is about two bushels, at intervals of about three weeks.

Artificial Manures.

The artificial manures at present most prominent before the agricultural community are divided into two classes, viz: MANIPULATED GUANOS, which assume to be equal parts of Mexican and Peruvian Guanos intimately mixed, and Biphosphate of Lime or Superphosphate of Lime, which are Bones or the Phosphatic Guanos dissolved in Sulphuric Acid. At present I do not know at what price the former manure is now sold, but if it is properly *made*, out of the best *materials*, and the vendors of this manure are from previous education and study, fully competent to the duties of the selection and manipulation, then heretofore it has been sold at a price far above its real intrinsic value.

The high price of crops, and an energetic spirit of improvement, have caused a demand for many other manures than those formerly used, and to meet this demand, manufacturers have introduced into our markets various compounds.

These have been recommended to the use of the farming community by recommendations from practical men who have used them, and have been endorsed, *without qualification*, by some "scientific men." I cannot too strongly caution farmers to beware of these manures. There have been manures extensively sold in our markets at a price very far above their real value, which price could not be obtained if farmers were correctly informed in relation to them. Compounds under names and with certificates calculated to deceive the public, are now so prominently advertised by means of pamphlets and the commercial and

agricultural press, that great caution is necessary in order to avoid deception. It will be well for farmers before being led away by certificates of the superiority of any manure over "best Peruvian guano," or equal mixtures of "best Peruvian and best Mexican," to ascertain if these guanos came from the same parties as sold the manure, and whether they were *really* what they assumed to be The business of making artificial manures is profitable in proportion to the amount of fraud practiced in it, and unfortunately professed men of science, have furnished their official position and name to the recommendation of such manures, and thus have become aids to gross imposition on the purchaser. Again, I say to all, beware of them, unless accompanied in every instance with a written guarantee as to the per cent. of ammonia and of biphosphate of lime they contain.

There have been manures sold in the Baltimore market under the name of "superphosphate of lime," which on analysis did contain not three per cent. of that article; as well might one call a coin a silver coin which only contained three per cent. of silver. There are manures also sold here the chief materials of which are bought in Baltimore, thence carried hundreds of miles to be *manufactured*, and then again brought back and sold to our farmers. Do they not have to pay thus double freight on these manures, and then trust to both the honesty and intelligence of a manufacturer for their purity and goodness? Manure dealers of this class can afford to advertise largely, for their profits are great, and although their manures may be heralded to the agricultural public as superior to the best Peruvian Guano, or as superseding it, yet such cannot be the case except *in very rare instances*. They are sold at a price above their value, and farmers will find to their cost, when it is too late for redress, that they have been induced to part with their hard earnings for comparatively worthless articles.

To prove this I have furnished a review of a publication made some time since, recommending a manure made in New York and sold here under the name of De-Burg's Superphosphate of Lime. Superphosphate of Lime for various reasons had become a popular one, amongst many farmers, in various parts of the country, and hence I presume the above name was chosen: it was sold here by agents of high mercantile credit and standing, and recommended by the chemist of the Maryland State Agricultural Society. All of these things had a tendency to induce public confidence in it, and therefore I feel it more my duty to examine into its merits; what these merits, or rather demerits, were, the following communication shows, and I only introduce it here for the purpose of cautioning planters and farmers against all similar sources of imposition for the future.

It was in reply to a gentleman who had always taken a deep interest in scientific and practical agriculture.

Dear Sir: I regret to inform you that I have not been able to make any analyses of the artificial manures now offered for sale in our market; having no more time at my disposal than is necessary to analyze the soils, marls, &c., of the particular counties in which I have been engaged. The office of my assistant expired on the 10th of last March, and, according to the decision of the Comptroller of the Treasury, the *Appropriation Bill did not, per se, continue his salary.* The law was not enacted to continue to the state the services of this eminently skillful and industrious gentleman, though several of the largest counties in the State have yet to be examined. The information which I shall give you must therefore be derived from what these manures say for themselves by their interpreted analyses.

The only manure which has recently been brought prominently before the public is one called "*C. B. DeBurg's Super Phosphate of Lime.*" This manure has been extensively advertised in the public papers, and also by means of printed sheets containing its analysis, and a recommendation by Dr. David Stewart, a Chemist of this city. From an attentive examination of the report on this manure, one of two conclusions must be formed: First, either the analysis must be incorrect; or, that this manure is sold under a false name, it being no "Super Phosphate."

"Super Phosphate of Lime," as we know, and as is particularly stated to us in the Baltimore Weekly "Sun" of May 20th, should be nothing else but bones (or other Phosphates) dissolved in sulphuric acid; and theory shows the mixture of both to be: For every 100 lbs. of raw bones 29 lbs. of oil of vitriol. Such a mixture would then contain about 21 lbs. of real sulphuric acid without water, and its composition would be pretty well represented by the following numbers:

Moisture	10
Animal Matter	27
containing of Nitrogen 1.25, equal to Ammonia, 1.5.	
Hydrated Sulphate of Lime (Plaster of Paris)	39
containing of real Sulphuric Acid, 18.	
Bi-Phosphate of Lime, soluble	24
containing of Phosphoric Acid 17.	

T. Thomas Way, Consulting Chemist to the Royal Agricultural Society of England, remarks that no neutral or insoluble Phosphate is mentioned, because it is supposed to be entirely converted into Bi-Phosphate (Super-Phosphate;) with it must be said, however, that it is practically impossible to do this. The manufacturer will either fall somewhat short of the entire decomposition of the Phosphate, or he will go beyond it, setting Phosphoric Acid free; which, to the consumer, is by no means an ob-

jection. But it is certainly an object to exceed rather than fall short of the mark, so as to leave none of the insoluble phosphate unacted on.

The above statement gives us the composition for the best article of "Super-Phosphate of Lime," and though it cannot be practically made in such a perfect manner as it is represented by the above numbers, it will, nevertheless, be the surest and most natural standard by which the quality of all fertilizers belonging to this class should be estimated.

Let us now see what Dr. Stewart says in his "Report of Analysis of a sample of C. B. DeBurg's Super-Phosphate of Lime." The following is a true copy of the published analysis, with an annexed recapitulation as given by him:

"*Report of Analysis of a sample of "C. B. DeBurg's Super Phosphate of Lime.*

February, 1854.

Proximate Analysis.

Water	16.40
Organic matter, Containing Ammonia	25.50
Ash	*58.10

Proximate Analysis of Above Ash.

Phosphoric acid	18.63
Lime	21.33
Magnesia	02.79
Insoluble residue	09.80
Salts, Potash and Soda, Sulphuric acid, &c	05.55
	*58.10

Total proportion of manure soluble in fresh cold water was found to be twenty-eight (28) per cent.—of *this* nearly two parts were Phosphoric Acid, viz: *valuable* elements soluble *in water*.

Phosphoric acid	1.81
Potash of Soda	2.00
Volatile compounds, containing Ammonia	16.15
Sulphuric acid, Lime, Magnesia and other elements of less importance	08.04
	28.00

Recapitulation.

Total proportion (per cent.) of valuable elements *in this "Chemical Manure"*—3.75 or nearly four per cent. of Nitrogen, equal to 4.54 or nearly five per cent. of Ammonia; 18.63 or nearly nineteen per cent.

of Phosphoric Acid, equal to 38.40 per cent. of Bone Phosphate of Lime, or nearly 39 per cent.; 1.81 or nearly 2 *of this* Phosphoric Acid is soluble in water, and is, therefore, equivalent in its effects of five times the Bone Phosphate of Lime that it represents. See Patent Office Report, 1852–3, Agricultural, page 391.

Making the most liberal allowance as above, and estimating bones to be worth $25 per 2,000 lbs., (ton) we may say that in consideration of the *soluble* Phosphoric Acid, the phosphates in this compound are worth, per ton.. $25 00

And the Ammonia..	10 00
Whereas, if we estimate the Phosphates in Peruvian guano at same rate, the 500 lbs. of Phosphates in Peruvian Guano would be................................	12 50
And the 320 lbs. of Ammonia in a ton of Peruvian Guano would be...	35 24
	$47 74

In view of the above analysis, I do not hesitate to say that this manure is cheaper to many farmers at forty dollars per ton than Peruvian Guano at fifty; and believing as I do, that there is no species of manure for any crop, and much less for all soils, I still reiterate the opinion expressed several years since, that these combinations of Peruvian Guano are more generally certain than the Guano alone, which fails on many farms to produce any good effect.

I have given its absolute value, or money value—also my opinion of its price—and it is my intention to apply one ton to my corn field this year where its use is indicated, and where I am sure it will compare favorably with any other manure. Respectfully,

David Stewart, M. D.

Baltimore, 79 North Eutaw Street.

We see at first sight that the above does not represent a Super Phosphate at all. Where is the necessary Sulphuric Acid? This is a question which the analysis cannot answer.

We read in one place:

"Salts, Potash and Soda, Sulphuric Acid, &c., 5.55," and at another:

"Potash and Soda."

Now if Potash and Soda make 2 per cent. by themselves, then, of course, Salts of Potash and Soda must make at least 5 per cent. Deduct these 5 per cent. from the whole amount allowed for Salts, Potash and Soda, Sulphuric Acid and &c., which is 5.55 as above mentioned, and we have half of one per cent. for Sulphuric Acid and &c., and therefore in a favorable case one-fourth of one per cent. of "&c." and one-fourth of one per cent. of "Sulphuric Acid." This amount of Sulphuric Acid is so small as must be considered an incidental impurity, and not as

the agent which had transformed common Phosphate of Lime into a soluble Bi-Phosphate or Superphosphate.

The analysis mentions 1.8 per cent. of Soluble Phosphoric Acid; this cannot be attributed to the action of Sulphuric Acid on the original Phosphates. Nobody need however be astonished at its presence who knows the action of Ammoniacal Salts on Phosphates. Ammoniacal Salts, especially Sulphate of Ammonia, dissolve pretty readily Phosphate of Lime, and to this fact the great effect of Peruvian Guano must to some extent be attributed. Peruvian Guano, as we know, contains Phosphate of Lime besides Ammonia; if this article is mixed with Sulphate of Lime (Plaster of Paris) or applied to a soil which contains originally Plaster of Paris, Sulphate of Ammonia is formed, which acts as a solvent to the Phosphate of Lime. We even know by experiments made with mixtures of Peruvian Guano and Mexican, (pure Phosphate of Lime,) that the Sulphate of Ammonia which is formed from 100 lbs. of Peruvian Guano makes available not only the Phosphate of Lime which these 100 lbs. contain, but that it acts also on additional qualities of Phosphate of Lime, which the Mexican Guano contained, and that for this reason the application of a mixture of Peruvian Guano and Mexican is in all cases far more economical and rational than the application of Peruvian Guano alone, provided that the soil is deficient in Phosphoric Acid.

Dr. Stewart shows Ammoniacal Salts to be present in C. B. DeBurg's Super Phosphate of Lime, and the presence of 1.8 per cent. of Soluble Phosphoric Acid must therefore be the consequence of the action of these Ammoniacal Salts on Phosphates; the absence of Sulphuric Acid, or any other stronger acid than Phosphoric, excludes every other reason for its presence. But if this is the case, (and no other case is possible from the analysis,) we will at once perceive a great mistake as to the valuation of the article. The value of the Ammoniacal Salts contained in the article is first estimated, then the value of its Phosphates, and finally the value of the Soluble Phosphoric Acid, which estimated to be equivalent to five times the proportion of Bone Phosphate of Lime that it represents. By these means the analyst estimates first the agents, which are Ammoniacal Salts and Phosphates, and secondly their reciprocal effect which produced Soluble Phosphoric Acid. Such a valuation is, however, totally wrong and liable to mislead farmers and Purchasers of this article. A hotel keeper who would charge for the beef and for roasting it, and finally for the resulting roast beef, would act on the same principle as that by which the money value of this article is estimated.

If I make "the most liberal allowance," as Dr. S. did in estimating the money value of this "fertilizer," allowing $25 for

2,000 lbs. of raw bones, and $50 for 2,240 lbs. of Peruvian Guano, I come to the following result:

If 2,000 lbs. of raw Bones, containing 23.61 per cent. of Phosphoric Acid, are worth $25, then 1 lb. of Phosphoric Acid is worth 5.3 cents.

Peruvian Guano, containing 14 per cent. of Phosphoric Acid and 16 per cent. of Ammonia, is therefore worth—

For its Phosphoric Acid....................................	$16 62
And for its Ammonia..	33 38
Total...	$50 00

And therefore 1 lb. of Ammonia is worth $9.31 cents.*

The above Super-Phosphate of Lime contains in 2000 lbs., as per Dr. Stewart's analysis,

373 lbs. of Phosphoric Acid, which at 5 3 cents are worth......	$19 76
And 90 lbs. of Ammonia, at 9.31 cts.,................................	8 38
Total value..	28 14

This is the real money value of the article as calculated from Dr. S's analysis, and if we estimate Peruvian Guano at fifty dollars the short ton, (its present price) then at most the article is not worth more than thirty-one or thirty-two dollars per ton, a price very far below that at which it is sold. You can buy the materials of this manure and apply them to your soil at a far less sum than the price for which this manure is sold here.

Thirty pounds of Peruvian Guano and seventy of Bones or of good quality Mexican Guano would make one hundred pounds of manure superior to "C. B. DeBurg's Super-Phosphate;" and you can distribute these over an acre much better by sowing them separately, than if they are mixed before being used. When you can purchase the elements of this manure then for about thirty-one or thirty-two dollars, and have a more thorough mixture by sowing them separately on your fields, why buy this or any other similar artificial manure? The valuation put on this manure by Dr. Stewart is entirely too high and is not warranted by the analysis made by him.

It has become quite the rage now to advertise these artificial manures as superior to best Peruvian Guano, and from many gentlemen of high integrity and skill in practical agriculture, certificates to the fact have been obtained.

The profits of the dealer in Peruvian Guano, if he sells a genuine article, are very small, but if he sells an artificial manure made of very cheap substances, then his profits are very great; they are just in proportion to the worthlessness of the materials

* This was at the price of Peruvian Guano when this article was written.

used. Many, indeed I believe all of the vendors of this class of manures also profess to sell Peruvian Guano; now it is their interest to sell as little of this Guano pure as possible, but to sell other compounds in its stead, and it is a statement capable of the fullest and most entire proof that the vendors of these manures have been buying old Guano bags with Barreda's mark on them at a much higher price than new bags of the same kind cost, and furthermore, the same parties have given in exchange first rate *new bags* of the same material for *old, worn out guano bags* with Barreda's marks on them. Why was this? what virtue was there in these old bags, except that they could be filled with even an inferior article, to the worthless artificial manure, and thereby large profits be received in passing it off for Peruvian Guano? But the Peruvian Guano as represented by this factitious article is certainly exceeded in effects by the manufactured article, then certificates are procured; purchasers are first cheated themselves, and afterwards made the instruments of cheating their fellow farmers. I put it to the intelligence and common sense of every man, if the above are not fair conclusions from the statements given, and of the truth of these statements there is most abundant proof.

What is the remedy for all this, and how can the agricultural community be protected? It should be done by an inspection of all these manures, the Inspector being required to *give bond* for faithful performance of duty, and moreover being competent by scientific skill to do that duty. Proper penalties should also be provided for all of its evasions and infractions. Neither are certificates of practical men, nor puffs by newspaper editors sufficient for the guidance or protection of agriculturists in the purchase of these manures, as they most frequently lead them astray. This is advice honestly, *knowingly* and faithfully given, and there can *now* be ascribed no interested motives to me in making these recommendations. It is not influenced by motives of ill will or personal dislike to any engaged in their manufacture or sale. I have had no cause for either. To any who know me this statement is unnecessary, but I have been so frequently assailed by men who are interested in these frauds and their hired advocates, that I here make the statement, which none can with truth deny.

The Legislature should provide efficient aid for the protection of farmers in the purchase of this class of manures, as they are now very strongly urged on the community.

I have not spoken, in this report, of mineral phosphorite or Bone Black; there is none of the former by *that name* offered for sale in our markets, and the latter is not at present offered to agriculturists, it being all engaged by the manufacturers of artificial manures.

INSPECTION OF PERUVIAN AND OTHER GUANOS.

I have in all my previous reports spoken of the necessity of a rigid inspection of this article, and although the Legislature has conceded this point in using the very language of my reports, and copied from them the preamble of the Bill for this purpose, yet that Bill in its provisions does not carry out the principles of an inspection capable of showing the true nature of the article inspected. Take one of its provisions as an example, which is that Peruvian guano capable of affording from 15 to 18 per cent. of ammonia shall be marked with the same mark, the letter A. Now we all know that the ammoniacal compounds in Peruvian guano are those which give it its distinctive value. The difference in the value of this guano then, which contains 15 pounds or 18 pounds of these compounds in the hundred pounds, is about 17 per cent., so that Peruvian guano at its present wholesale price of fifty-five dollars per ton, having the same mark, may have actually a difference in its value of nine dollars thirty cents per ton, the 18 per cent. of it being worth fifty-five dollars per ton, the fifteen per cent. is only worth $46 65 per ton or 17 per cent. less. The importance of the difference is much greater in other guanos.

There should be marked on each bag the name of the ship and the merchant be required to keep a certified analysis of its cargo.

With a few words for the truth of history on this subject and I am done. In a report to the Senate at January Session, 1854, in answer to a call of that body, the present Inspector (Dr. Wm. S. Reese) states that the present law was drawn up with great care by Dr. Washington Finley, of Queen Ann's county. This is an error, the same bill almost word for word was presented to the House of Delegates several years before, and was drawn up by Joseph Weathers, then chairman of committee on inspections, and revised by Hon. Otho Scott, and though it is true that the present bill as it stands did pass both houses unanimously, its friends only at *first* defeated the Senate "bill for the regulation of the inspection of guano" by four votes in the House of Delegates. This bill had passed the Senate by a vote of eighteen to two. It provided for *an accurate inspection, the inspector to give* $15,000 *bond for faithful performance of duty, and required the State chemist to be the inspector, or responsible for its faithful performance.* It was defeated in the House by the want of four votes. It could have been passed there had I, the State Chemist, acceded to a proposition giving the power of appointment of my assistant to a particular individual who made the proposition to me. This for obvious reasons I declined doing, and being opposed by strong *outside influence* and supported by none, the bill

did not pass. A part of the above statements the journals of the House and Senate will prove, AND FOR THE OTHER PART I HAVE LIVING EVIDENCE AND WRITTEN PROOF.

Having thus far treated exclusively of the composition of the soil and its formation, of manures, their properties, composition, uses, and mode of application, and indeed of every thing at present known capable of leading to their proper and economical application, I now come to speak of the soils of such counties as have been visited by me since my last report.

I refer to Carroll and Baltimore counties, and the tide water part of Harford county.

As I have been by some newspapers, and perhaps orally by some persons, (both being influenced by any other than truthful or honest motives,) accused of neglecting my duty, I here state that, whenever I have commenced to make an examination of a county, I have caused the fact to be announced in all of its public papers as well as those in the City of Baltimore having the largest circulation, and have in the former, *at my own expense*, given proper direction for the taking of samples of soil, &c., and that in every instance where these directions have been complied with, the analyses have been made, and furnished their owners; I have also desired in these advertisements that any person or persons who required my services in any part of the counties for particular examinations, should receive them on my being informed of their wish; to all of these requests I have attended when it was *proper* for me to do so.

CARROLL COUNTY.

This county, formed out of part of Baltimore and Frederick counties, is bounded by Mason's and Dixon's Line on the north, by Frederick county on the west, by the Patapsco river separating it from Howard county on the south, and by Baltimore county on the east. This county being formed for the convenience of the citizens in it out of the counties from which it was formed, its boundaries were made for their political convenience and not as divisions between separate varieties of soil or different geological formations. Some of its soils are therefore similar to those in Frederick and other counties, as only a line (that which has length without breadth) divides them.

Red Lands: Beginning in the northwestern part of the county and extending our route through the Middleburg and Taneytown Districts, and in some parts of Uniontown, until we meet with the mica slate soils hereafter to be described, we have a variety of soils known as red lands, similar in geological formation with those found in Frederick county, as described in my last report, and only differing in their agricultural value in being more decomposed, and having generally a deeper soil. They are underlaid by compact shales, sometimes,

these are represented by red sandstones sufficiently hard and compact to form good building stone. The value of these lands is materially influenced by the proximity of these shales or sandstones to the surface—where they lie near to it, the soil is unproductive, being liable to injury by droughts, as there is not sufficient depth of soil to retain a supply of water for the use of the crops in dry weather. When this is the case the soil should be ploughed as deeply as possible and manured with lime, containing a small per centage of magnesia—when basins occur they should always be drained, though these drains involve the expense of cutting through ledges of such rocks as occur on these lands, for when the water which falls on them can only escape by evaporation, good crops can never be produced.

Without giving here the various analyses of this class of soils, which were made from specimens taken from near Middleburg, from Dr. Leggett's farm, from Mr. S. Reindollar's, near Taneytown, from Mr. Bassett's, from Col. Piper's, of the Antrem estate, one of the most beautiful and elegant and productive of the estates of Maryland, and from various other places, I will only name the proper manures for their improvement. The necessary quantities and mode of application of these I have already shown under their appropriate heads, to which I refer those interested.

First, they should be manured with a limestone, containing a small quantity of magnesia, and if it contains other substances capable of absorbing, when burnt the food of plants from the atmosphere, so much the better. There is a limestone known in the neighborhood as Rheinhart's, which contains in its natural state about eleven and a half per cent. of carbonate of magnesia, and which contains of sand, talc slate and other similar constituents, about twenty per cent. When this limestone is burnt, these talc slates, sand, &c., form combinations with the lime and become strong absorbants, and retainers of all that which the atmosphere affords to crops, especially of ammonia; it when applied to these soils will not only improve their mechanical texture, making them when stiff, more loamy, light and porous, when too light and loose, more stiff, compact and retentive, but will at the same time afford the means of giving them the quick acting substance, ammonia. It has all the *permanent* effects of pure lime, and to some extent the immediate influence of Peruvian guano. The experience of the best practical farmers of this section of the country have confirmed this opinion.

These soils are uniformily deficient in plaster and salt; these should be applied to the crops in the mode pointed out in the section treating of these articles. Whenever these lands are too wet, and in many places this is the case, they should be thoroughly ditched and drained; without this, no return need be expected from labor, nor remuneration for expenses in manures. Where the rocks and shales lie near to the surface, the first thing to be done is to prevent the loss of soil by the effect of the washing of heavy rains, and to effect this, I know of no better plan than surface drains, made with a plow, and subsequently cleaned out with the hoe, sufficiently near to each other to carry off all the surplus water of the soil; the water by these means being distributed in many channels, can no where collect in sufficient abundance to carry off the soil and make unsightly gullies. These drains should have but a slight fall, and end by conveying the water to a fence, woodland or some stream.

In these locations, soils should be plowed deeply, as the deeper the soil the more room would the surplus water have to diffuse itself and prevent injurious washing.

The benefits resulting from the above recommendations will be two fold, first, the direct saving of a large quantity of land, for when the whole mass of the soil is washed off, some years must elapse before the hard shaly subsoil becomes sufficiently disintegrated and decomposed to furnish a good foundation for crops; secondly, the retention of the finely divided particles of soil, that part which contributes directly to the nourishment of the plant, from being

washed out by a large mass of water rapidly passing through it. Indeed, on all this variety of soils we must recommend deep plowing, and on the stiff heavy parts of it, the turning in of green clover crops. *With regard to the nutrient manures necessary to meet its deficiencies, I can best advise that phosphate of lime, whether in the form of Phosphatic guanos, bone dust, or superphosphate of lime, be but sparingly applied, and that only on soils that have been a long time in cultivation and not well manured.* Where these soils are deep and have been well improved, the use of stable manure preserved as I have directed, with the addition of one hundred pounds of good Peruvian guano to the wheat crop, will supply an abundance of phosphoric acid to soils that have been well improved with a deep soil, that is, 'one where the shales do not come near to the surface,' for a full rotation. On these shallow soils phosphoric acid in some form is necessary, because they do not contain it in sufficient abundance to meet the wants of a large crop. This defect can be readily explained. The phosphate of lime, whose valuable constituent is phosphoric acid, is liable to continual depreciation in soils from two causes: first, removal by crops; secondly, its removal by the rain water, which dissolves and carries it off; its supply is afforded by two ways, first, its direct supply by means of manures containing this substance, and secondly, its deposition in the soil in being brought up from the subsoil during droughts, the beneficial influences of which I have explained in my former Reports. On soils which have but little depth, and whose subsoil is impermeable to water, no supply of phosphoric acid or any other mineral substance can be received by the agency of the latter cause; they are therefore liable to continual loss of this substance by reason of the two foregoing causes, and are deprived of any supply by drought; they, therefore, other things being equal, will soonest become deprived of their soluble saline ingredients, and soonest of those which exist in the least quantity, therefore only on shallow soils and hill sides should substances containing phosphate of lime be applied.

On these soils sulphuric acid and chlorine are deficient, and are to be supplied by plaster of Paris and common salt, according to directions before given.

Adjoining these soils and separated from them by an almost imperceptible gradation, for they run into each other so imperceptibly that we can hardly tell exactly where the one ends, and the other begins, is a class of soils known as

Slate Soils.—These are a continuation of those found in Frederick County, and differ materially from the red land described above. The slates from which the soils overlying them are formed, are either mica slate, talc slate, chlorite slate, and blue or roofing slate, the composition of all of these is in an agricultural point of view, so nearly allied as to render any separate description of them unnecessary; besides this they are so intimately mixed, that it would require almost innumerable, certainly, with the means at my disposal, an impossible number of analyses to determine the special composition of each.

The land drained by the water of Little Pipe Creek and its tributary branches, are composed mainly from the disintegrated particles of these rocks or slates; they have by various influences become thoroughly decomposed, have been well manured, and well cultivated, and are equal in production to the average of the best in our State. These lands are formed from the same rocks, and have the same composition in every particular, with all the lands in this section of the State underlaid by the slates which I have above spoken of, why should some of these be barren and some so productive? why should the soils of the same formation on Parr's Ridge, running through the County to Manchester, and the Pennsylvania line, be generally unproductive? We must look to their mechanical texture for an explanation of their different degrees of fertility. Most of the soil in this part of the county, as it has been formed, has been washed off, and there has not been enough of it left to meet the wants of plants, in retaining a sufficiency of moisture for their support, or a sufficiency of nutrient materials to develop their growth or structure.

To obviate these difficulties we must first, deepen the soil; secondly, decompose and set free the minerals which it has in a crude state.

The first of these indications to be fulfilled by means of deep plowing and thorough cultivation, the second, by the application of a lime which contains no magnesia, that is, pure lime,

For limes of this class, the analyses of various limestones heretofore made by me can be consulted.

In this connection I will here mention a limestone belonging to "Ephraim Tracey, Dug Hill, three miles from Manchester," as a very superior agricultural lime, for all of the soils of this class, and they mostly surround it.

It contains about eighty per cent. of pure carbonate of lime, (air-slaked lime) and the balance of chlorite and mica slate, which combining with the lime when it is burnt, affords most valuable manure.

We have also the *light red sandy loams* of this county, at the foot of Parr's Ridge, represented by the land of Messrs. Davis, Dorsey, Bentz and others, which extend over the whole county in a line more or less directly parallel with Parr's Ridge. They are famous for producing a variety of Tobacco, known as Bay Tobacco, which always sells at a very high price.

These are best improved permanently by small additions of magnesia lime, air-slaked, that is, put out in heaps, suffered to remain for a long period of time before being applied to the soil, small quantities of Peruvian Guano should be applied to the wheat crop.

Red Clay Loams, this variety of soil begins at the eastern border of the above described soils, and extends eastward to where they meet the granite or isinglass soils.

The proper treatment for these Red Clay Loams is a dressing of *pure air-slaked lime*, as a permanent improvement of their texture, and the use of small quantities of Peruvian Guano as a means of giving a quick, early start to the crop.

The next variety of soils we meet in going eastward from these, is the *white isinglass*, soils formed from the disintegration of granite rocks. These soils are easily recognized as having in them bright shining spangles of mica or isinglass, they are exceedingly light and dry, and in their present condition are very poor and barren. They have in them, however, nearly all the requisite substances of a fertile soil, and can be made perfect as to their physical texture by means of the application of quick or water-slaked lime. This will at once give the soil more binding and retentive power, and improve its texture. The lime should be put on in the fall after the land is ploughed for the spring crop, and well harrowed in; to those spring crops Phosphate of Lime should be applied in manner and quantity according to directions previously given. When wheat is sown Peruvian Guano should be used.

These comprise all of the *chief* varieties of soil in Carroll County, they follow each other in regular succession, from west to east, in the order in which they are named, and can easily be recognized by their location as well as by their description.

I have given the above recommendations from many analyses of each variety of soil, and from the congregated practical experience of those who have lived on, and improved it. These different varieties run through Carroll County, and are found in corresponding localities in the adjoining county of Baltimore.

LIMESTONES OF CARROLL COUNTY.

There are very many of them used only in the neighborhood of their existence, and which have not been handed to me for examination. After making a call through the public papers for samples of limestones from those who wished them analyzed, I did not deem it my duty to take samples from those who declined to furnish them for the purpose of analysis.

Whenever required, I have complied with requests made both for analysis and subsequent publication.

Carroll county contains many prime quarries of limestones, both for agricultural and building purposes.

The principal limestones in the upper part of Carroll co., are the following:

No. 1. A white Limestone of fine crystalline texture.—Haines, Uniontown, Md.

No. 2. A dark gray variety, slatish and with crystals of Calcspar imbedded. Rhinehart, Carroll county.

No. 3. A dark gray and homogeneous mass, of fine crystalline texture and small white veins of Calcspar traversing.—Torrey's, Adams county, Pa.

They were found to be composed as follows:

	No 1.	No. 2.	No. 3.
Carbonate of Lime,	99.5	68.3	98.8
Carbonate of Magnesia,		11.5	0.5
Sand, Slate, &c.,	0.5	20.2	0.7
	100.		
And will, therefore, when burnt, produce, of—			
Caustic Lime,	56.0	38.3	55.
Caustic Magnesia,		5.5	0.2
and, when water-slacked, of—			
Water-slacked Lime,	73.7	50.6	73.1
Water-slacked Magnesia,		8.0	0.3

There yet remained for this Report a description of Baltimore county and the tide-water part of Harford, and the analyses of Soils, Limestones and other minerals of *public* interest, the analyses all having been made and the notes of the description of the various sections of this part of the State taken from observation on the spot, but not written out in a form fit for the press. This could have been done in a few days, and would have been done by the present time but for the sickness of the writer, and at as early a period as your predecessors have received the report. The printer of my Report showed me on yesterday, Feb. 22d, a note from the printer to your Honorable Body, of which the following is a copy:

Feb. 21, 1858.

Sherwood & Co.

Gentlemen:—If Dr. Higgins does not furnish you with the balance of the copy of his Report by 5 o'clock, P. M., on Tuesday next, the 23d inst., I order that the work be closed and put in the binder's hands immediately thereafter.

Respectfully, Thos. J. Wilson.

From this imperious note there was no appeal, which I much regret. There were several subjects to which I wished to call the attention of your Honorable Body and the people of the State. One I will mention. Let the State Chemist (if that office be continued) have the selection of his own printer, and give him proper means to carry on his work. Then the Reports can be laid on your desks in the early part of the session.

In the Supplementary Report to be made to His Excellency the Governor, before the expiration of my term of office, the two counties of Baltimore and Harford will be exclusively attended to.

The law gives the Governor the power of printing the same, and it can be franked to all of the people of these counties. This Report will be much more complete and full, than if the same subjects had been included here; as there will be time for careful examination and correction of all errors, which was not allowed for the present one.

I much regret to make so abrupt a conclusion to this my last Report to your honorable body, from whom I have received nothing but marks of high consideration and kindness. To you and those whom you represent, with many of whom I have been on terms of affectionate intimacy for many years, I tender my sincere wishes for peace, prosperity and happiness.

They are well remembered, and this is my sincere thought for them.

JAMES HIGGINS.

APPENDIX.

AN ESSAY ON THE ANALYSIS OF SOILS,

WITH A FORMULA FOR THE SAME,

As Founded on the Relations between Soils and Plants.

BY CHARLES BICKELL, PH. D.

CHAPTER I.

SUBJECT.

The laws of vegetable life, as well as the phenomena and processes which constitute its nature, are entirely founded on and supported by the actions of agents which, under the influence of heat and light, exist in the atmosphere and in the solid crust of our globe. Both the air and earth supply plants either directly or indirectly with crude nourishment, indispensable for their growth, which they assimilate and transform into new compounds of organic form and character. In the first case, it is the original constituents of the air and earth which cause development of vegetable life; in the latter, these nourishments are the products of the mutual action of the atmosphere and earth on each other.

The study of the constituents of the air and earth and their reciprocal action upon each other, must therefore, form the natural basis of our knowledge of the formation and necessary conditions of a soil, which may be favorable to the growth of cultivated plants.

Constituents of the Atmosphere.—*Oxygen—Nitrogen—Carbonic Acid—Ammonia—Water.*

The constituents of the atmospheric air are either *fundamental*, viz: Oxygen and Nitrogen, which form its main bulk, and remain in a constant proportion to each other; or *accidental*, viz: Carbonic Acid, Ammonia and Water, which must be considered as merely admixtures, with which the atmosphere is supplied from many sources. The quantitative proportions of the latter, depending on

local causes, vary; but they are never entirely absent, and they participate in the affairs of nature with an influence equal to that of the former. There are a few other substances, viz: Sulphureted, Carbureted, Phosphoreted Hydrogen, Miasma, &c., also diffused through the atmosphere in minute quantities, but they do not seem to exercise a particular influence on vegetable life, and may therefore be here disregarded.

Oxygen, indisputably the most important constituent of the atmosphere, is characterized by its affinity for combustible substances, in consequence of which it produces those phenomena which in common language are termed combustion, eremacausis, fermentation, &c. The metals e. g. are combustible substances, and it is owing to this circumstance, that we so seldom find them on the surface of our globe in the metalic state. We find them already burnt or oxydized, viz: in their combination with oxygen, as earthy substances, called Oxyds. Substances of organic nature and origin also become exposed to the influence of the atmospheric oxygen, as soon as the vital powers have ceased to exist in them. Under this influence they are decomposed and converted into new substances, which contain Oxygen as a constituent part.

In all these cases, Oxygen is consumed, and as it is furnished by the atmosphere, the quantity contained in it should become less and less; a conclusion, however, not confirmed by practical experience. Philosophers have by direct experiment, succeeded in discovering the source from which Oxygen is replaced in the atmosphere, in the same proportion as it is furnished by it to support the processes just mentioned. Their observations have shown, that whilst dead bodies of organic origin absorb Oxygen from the atmosphere, and consequently decay; living plants, on the contrary, separate Oxygen from its combinations, retain and assimilate the substance which was united with Oxygen, and consequently grow and develop themselves. For Carbonic Acid, a product of the combustion of organic matter, consisting of Carbon and Oxygen, becomes decomposed when brought in contact with green leaves in such a manner that its carbon is assimilated by them as food, whilst its Oxygen liberated assumes the gaseous form and is diffused through the atmosphere.

Nitrogen is also a fundamental constituent of the atmosphere, and must likewise be considered as a highly important substance, though it takes no active part in the processes of life. Nitrogen is, as to its properties, the opposite of Oxygen Whilst the latter has a strong affinity to combine with other substances producing phenomena which have been mentioned before, the former manifests in this respect, such a degree of indifference, that only in rare and local cases, e. g. by the action of electricity, is a direct union of Nitrogen with other substances effected. But to this inactivity which characterizes Nitrogen, its high importance as a constituent of the atmosphere must be attributed. The quantitative proportion

in which both Oxygen and Nitrogen form the atmosphere, is by their weight about 23 per cent. of the former, to 77 per cent. of the latter. Each particle of Oxygen is therefore mixed with about 4 particles of Nitrogen. By this arrangement a dilution of the pure Oxygen is effected and consequently its destructive influence upon living and dead bodies diminished, to such an extent as is in best accordance with the wants of nature.

Carbonic Acid is the product of the decomposition of organic substances, arising from the combination of Carbon with atmospheric oxygen. All organic substances consist chiefly of Carbon; and therefore when oxydized, produce Carbonic Acid, which escapes in gaseous form, and diffuses itself through the atmosphere.

The functions which this constituent of the atmosphere performs, are of high importance in the economy of nature. It is not alone the chief nourishment of plants, which by separating the Oxygen, appropriate to themselves its Carbon; but in its chemical character, which is that of a weak acid, it is a powerful agent under the influence of which, as will be seen below, the process of the degradation of rocks and formation of soils is produced. The quantity of Carbonic Acid contained in the atmosphere is not constant—it ranges however between certain limits, and depends on many particular circumstances; e. g. on the season of the year, on the time of the day, on the locality, on the weather, &c.

Ammonia, a substance composed of Hydrogen and Nitrogen, is also a product of the decomposition of organic bodies, (which contain Nitrogen,) and for this reason is likewise diffused through the atmosphere, of which it makes a constituent; and to it we must also ascribe important functions, though its quantity is comparatively very small. Experiments expressly made to ascertain its importance, have shown that plants can live and develop themselves without having any other source capable of furnishing them with Nitrogen, but the Ammonia contained in the atmosphere; and if practical experience has shown that a rational husbandman should not always rely on this supply of Nitrogen, the result of the experiments just mentioned nevertheless teaches us a fact which throws sufficient light on the high importance of this substance.

Water is, in the form of gas and vapor, another constituent of the atmosphere, of which it forms about one per cent. of its volume. Its quantity, however, varies very much on account of circumstances which have been noticed already, when speaking of Carbonic Acid. It originates in exhalations from the surface of our globe, and is dissolved by the atmosphere in form of a gas, the specific gravity of which is much lighter than that of the atmosphere itself. For this reason, it goes up to a certain height, where it is collected and finally condensed to water (clouds,) which when heavy, falls down (as rain) to its original place, the surface of our globe. Rain-water contains in solution small quantities of all the constituents of the

atmosphere. Their quantitative proportion differs however from that in which they exist in the air, and is characterized by a more predominant quantity of Oxygen and Carbonic Acid.

THE CONSTITUENTS OF THE EARTH.—*Earthy masses—Rocks with crystalline texture.*

The solid crust of our globe is composed either of *earthy masses*, more or less loose and friable, or of hard and compact *rocks with crystalline texture.* The former are called aqueous rocks; are the most extensive, at least in the horizontal direction; and were precipated from their solution or suspension in water, in the form of plainly visible parallel layers, called strata. They may be classed as follows:

Calcareous Rocks and Salts.	*Broken Masses.*
Limestone,	Sand-stone,
Dolomite,	Clay,
Anhydrite,	Calcareous Conglomerations,
Gypsum,	Breccia,
Rock Salt,	Tufa,

Organic Rocks.
Coal.

The latter are called volcanic rocks, are of igneous origin, produced by the action of subterranean heat, and form massive blocks, especially extending in the vertical direction and without any regularity in the arrangement of their particles. They very probably existed once in a fused state, forming a liquid and homogeneous mass, from which, on cooling, such constituents were separated as had the greatest tendency to crystallize, whereby the entire mass assumed a peculiar crystalline texture. The various crystalline rocks can best be classed as follows:

Silicates, containing Alumina and Alkalies.		*Silicates, containing Lime and Protoxyd of Iron.*	
Granite,	Felsparphophyrite,	Hyperit,	Melaphyrite,
Gneiss,	Phonolite,	Gabbro,	Dolerite,
Granulite,	Trachyte,	Syenite,	Basalt,
Mica-Slate,	Obsidian,	Diorite,	Leucitopyrite.

ACTION OF THE ATMOSPHERE ON EARTH.—*Mechanical Influences—Chemical Influences.*

Geology teaches us that there was a time when no plants were developed upon our globe; when neither soils nor any friable masses of earth existed; at that time the entire crust of our globe consisted solely of those hard and compact rocks of a crystalline

texture, which have just been named. These crystalline rocks have therefore furnished the material for all the immense masses which, in parallel layers, now cover the surface of our globe, and more particularly the material for that portion of the earth which forms the soil—its outer crust. The study of the influences to which, during thousands of years, these crystalline rocks were exposed and in consequence of which they became loose and friable, and were converted into new forms of various character, capable of supporting vegetable life, must therefore form the natural basis for understanding in what manner the wants of plants depend on the soil, as also the manner in which those wants may be supplied.

The degradation of rocks,—a term applied to the natural changes they undergo,—takes place under the double influence of mechanical powers and chemical affinity.

The commencement of this process manifests itself in the formation of small clefts and fissures, which extend through the body of the rocks, a phenomenon the consequence of changes in their temperature. We know that all substances, without exception, are expanded under the influence of heat and contracted again by cooling; the degree of this expansion is however not the same in different substances submitted to the same temperature. The chrystalline rocks, of which alone we here speak, are always an aggregation of different minerals. Changes in the temperature to which they are periodically exposed, consequently effect an unequal expansion or contraction of these different constituent minerals; besides this, the surface of the rock is more directly warmed or cooled, and therefore more expanded or contracted, than the interior. The consequence of these influences, is the production of small clefts or fissures, which originating on the surface, gradually extend themselves towards the centre, and thus weaken the cohesion of the whole mass.

To the effects of heat on solid masses, we must also add those occasioned by water. The property inherent in water, to occupy a larger space when frozen, than in the liquid state, aids materially the preceding influences in destroying the cohesion of rocks. It is a well known fact that this increase of the bulk of water when frozen, is able to overcome any resistance however great, which may oppose it. In Autumn, the season in which rains usually fall, we find mountainous countries very moist; the caverns and fissures of the rocks filled with water, which gradually leaks through the smaller clefts, percolates through the pores and finally pervades every part of the rock. The inclosed water converted by the first frost into ice, expands and bursts the rocks, which oppose its expansion, and by these means aids materially in their comminution.

Besides, water when falling to the earth in the form of rain, and running from mountainous regions to level countries, and also air, by its weight when in motion, act mechanically on rocks and materially contribute to their degradation.

But all of these mechanical influences which act on solid rocks, powerful as they are and as great a share they take in their destruction, would not have been able to effect such changes by themselves as have taken place, and as were necessary to render the surface of our globe fit for the support of vegetable life. Every thing which happens in nature, is based upon endless and mutual actions; no process whatever stands isolated, its whole economy must be understood before even the most simple phenomena in all their conditions and consequences can be explained—so in this instance. The mechanical powers are not the only causes of the degradation of rocks; these are accompanied and assisted by chemical affinity, the activity of which is due to the following facts:

A piece of granite protected against all mechanical influences which could destroy it, would nevertheless lose its cohesion and finally become changed into a white powder, commencing at the surface, and gradually extending to the centre of the stone. This change is due to the influence which the constituents of the atmosphere, most especially Oxygen, Carbonic Acid and Water, exercise upon solid rocks. The different crystalline rocks are composed of only a limited number of single minerals, which by the different manner of their association, as well as by the different quantitative proportions of which they are united, produce the various forms above named. These single minerals are: Quartz, Mica, Felspar, Augite and Hornblende, of which the three first, in their various combinations, form the first class of crystalline rocks, headed: Silicates, containing Alumina and Alkalies. The three latter, on the other side, form the second class of crystalline rocks, headed: Silicates, containing Lime and Protoxyd of Iron.

Granite is the representative of the first class, and an investigation of the causes which lead to its degradation, is sufficient to explain those which effect that of all others of this class. Granite consists of Quartz, Felspar and Mica, of which only the two latter are subject to the influence of the atmosphere. Quartz is a form of Silicic acid, a substance which presents itself in two different modifications. In the one, its pure state, it is isolated, forming Quartz, which is in no way attacked by the atmosphere, and only liable to crumble to pieces under the influence of mechanical powers. When thus broken, it gave rise originally and still adds to the immense deposits of *Sandstone*, which we meet almost every where on the surface of the earth. In its other modification, it forms with Alumina and the Alkalies, Felspar and Mica, and in these it exists in chemical combination, forming a Silicate of Alumina and Potash, a substance which is subject to the influence of the atmosphere. In contact with the Carbonic Acid and the water of the air, it is so decomposed that Carbonate of Potash and an Acid Silicate of Potash are formed, both soluble in water. If these products are washed out by water, nothing will remain, but Silicate of Alumina,

a substance which, when pure, is of a white color and knc the name of *Kaolin;* in its impure state, however, it is colored and ·ompanied by Lime, Sand, Oxyds of Iron, &c., forming the various kinds of *Clay*.

A knowledge of the composition of Granite, therefore, explains to us the origin and formation of two massy deposits: Sandstone and Clay, which almost every where cover and often extend to thousands of feet below the surface of the globe, and which also form the fundamental constituents of the soil.

The second class of crystalline rocks, headed: Silicates, containing Lime and Protoxyd of Iron, consists either of rocks containing Felspar, associated with Hornblende, or Felspar associated with Augite; and their degradation under the influence of the atmosphere, is especially due to the influence of the atmospheric Oxygen on Protoxyd of Iron. Hornblende, as well as Augite, contains Protoxyd of Iron, a substance to which both minerals owe their dark and somewhat green color, and which greedily attracts oxygen from the air, in order to procure for itself a higher degree of oxydation—that of the Peroxyd of Iron. The immediate consequence of this change, is the formation of new combinations, which produce an alteration in the position of the atoms, (the smallest parts of the rocks;) so that the original solidity of the rocks is diminished and a continued crumbling into small pieces, and in the course of time a complete disunion of them takes place. Common Copperas also contains the Protoxyd of Iron, and exposed to the influence of the air, is modified in an analogous manner.

If Sulphurets (combinations of Metals with Sulphur) occur in crystalline rocks, which is frequently the case, the degradation of them takes place still more readily, inasmuch as these ingredients also absorb Oxygen and become transformed into Sulphates, soluble in water.

The capacity then of the crystalline rocks for decomposition, is in proportion to the quantity of Silicate of Potash they contain, and also of such other substances as absorb Oxygen, and in this way have a change of their chemical composition. We always find that the larger the quantity of these substances, the more quickly and thoroughly is the exposed rock decomposed.

Formation and Constituents of the Soil.

We have thus represented to us in a sensible form, the influence by which the gradual degradation of the primitive crystalline rocks was effected; and also the consequences of this process, which gave rise to the formation of new masses of an earthy and friable character, permeable to the roots of plants, and thereby rendering them their necessary mechanical support. We find these masses, either in their original place, still covering the crystalline rocks by

the degradation of which they were formed, or as aqueous formations of different periods and ages, appearing in distant regions throughout the surface of our globe, to which they were conveyed by rivers and streams or by mighty floods, as they occurred in former ages.

The soil (the upper portion of these masses) consists, according to the above, of *Quartz-Sand;* of smaller or larger *fragments of rocks* which still remain undecomposed; and of *Clay*, impregnated with Silicates of Potash and Soda, Lime, Magnesia, Oxyds of Iron, &c. A fertile soil, however, requires besides these ingredients, comparatively small quantities of some other substances, viz: such as contain Phosphoric Acid, Sulphuric Acid and Chlorine, the origin of each of which is also easily explained. For Phosphoric Acid is the constituent of Apatite, (Phosphate of Lime)—a mineral which, though in small quantities, is diffused through almost all rocks of all ages, and consequently carried along with the products of their degradation. Sulphuric Acid originates from Sulphurets, combinations of metals with sulphur, which also are more generally diffused through rocks, and which under the influence of the atmospheric Oxygen, are converted into the sulphates of the corresponding metals as already explained. Chlorine in its combination with Soda, (common Salt,) we meet in abundance in sea-water; in the waters of fountains and also in small quantities in rain-water.

Another substance which is never absent in cultivated soils, is Humus. It has already been mentioned, that after death, the constituents of organic bodies (the organs) become exposed to the destroying influences of the atmosphere, which finally converts them into Water, Carbonic Acid and Ammonia. In the meantime, between death and total conversion into these three constituents of the atmosphere, the remaining organic parts run through many phases of decomposition, and in this period form the so called Humus; a substance which, therefore, in every moment changes its composition. With every new crop we take from our soils, we also supply them with new quantities of Humus, which originates from those parts of the plants that remain upon the soil. For this reason, a soil cannot become poorer in Humus though its quantity is constantly diminished by decomposition.

The Constituents of Plants, and the Forms in which they are assimilated.

A plant, or any part of it, when heated to a proper degree of heat in the open air, burns, and produces volatile substances, which in gaseous form are diffused through the atmosphere, whilst only a comparatively small part of the original plant remains as an incombustible, earthy substance, called the ash.

Far the greatest part of the plant produces the volatile matter, consisting of Carbonic Acid, Water and Ammonia, three substances which can be farther divided into their elementary constituents: Carbon, Hydrogen, Nitrogen and Oxygen.

These single substances, are the fundamental constituents of all organic bodies; and plants must therefore be constantly supplied with them whilst the processes of life continue to take place in them.

Animals live on both vegetable and animal food, and are consequently referred to, and supported by the vegetable kingdom; they could not exist before vegetation covered the lifeless mineral crust of our globe. Plants, on the other hand, must necessarily assign to themselves food of far more simple constitution. When they first made their appearance, they did not find any thing else offered to them for food, but what already existed as constituent parts of the atmosphere, and earth.

In accordance with this, our daily experience teaches us, that the wants of plants are supplied by both these media, viz: that the forms in which the plants assimilate their Carbon, Hydrogen, Nitrogen and Oxygen, are those of Carbonic Acid, Water and Ammonia, contained in, and furnished by, the air; and that, on the other hand, the forms in which the plants assimilate the constituents of their ashes, are those of Silicates, Phosphates, Sulphates, Chlorides, alkaline, and earthy salts, as contained in, and furnished by, the soil.

The latter position cannot be doubted; no other source exists for the supply of mineral substances, but the earth. As to the former however, that Carbonic Acid, Water and Ammonia, are the only forms which supply the organic constituents of plants, it has been often opposed, and is still opposed by many at the present day.—it is a fact that the productiveness of soils is somewhat influenced by the quantity of Humus contained in them, and accordingly the principal objection made against our theory is this, viz: that Humus is assimilated by the plants in form of Humus, and thus participates directly in the formation of the organic parts of plants, or, in other words, plants live on organized bodies.

We have no reason to adopt a theory which is not only strongly opposed to natural philosophy, but which is also positively contradicted by facts. We see plants growing and becoming developed in a soil which neither contains Humus, nor any substance of organic origin. This occurs in many parts of our globe, and is also confirmed by direct experiments, upon soils which before being used, had been calcined, and thus deprived of all organic matter.

On the other side, the plant is not able to appropriate to itself and to assimilate its constituents, in their isolated, elementary form; for a plant which is planted in pure charcoal, and surrounded by an atmosphere of Hydrogen, Nitrogen and Oxygen, will soon die for want of suitable nourishment.

For these reasons we are compelled to seek for the nourishment of plants in the contents of the atmosphere: and as Oxygen and Nitrogen cannot add to the weight of organic bodies in their isolated form, these functions must be solely fulfilled by Carbonic Acid, Ammonia and Water. If we abstract from Humus its action on the mechanical texture of soils, its beneficial influence on vegetation is then due to its giving rise to Carbonic Acid, Ammonia and Water, and to no other cause.

It has already been shown that Carbonic Acid, Ammonia and Water, are the products of the decomposition of organic substances; and we have seen that they are also assimilated by plants as nourishment, and their elements, under the dominion of the vital powers, arranged to form new compounds of organic character.—The same substances which have served to produce the plant, are thus regenerated after its death by the process of its decay, thus forming an eternal transition from the organic state to the inorganic.

The inorganic, or mineral, constituents of plants, though small in quantity when compared with the organic part, are nevertheless essential, and must be considered just as indispensable for their growth as are Carbonic Acid, Ammonia and Water. For the proof of this, it is only necessary to let experiments speak. The result of observations made by the Prince of Salm-Horstmar in this matter, are especially interesting, and have established the following facts: In a mixture containing all the various substances requisite for the nourishment of plants, except Silicic Acid, Oat plants remained low, pale and dwarfish; without lime, they died after the second leaf; without Potash and Soda, they reached only a height of three inches; without Magnesia, they remained weak and lying down; without Phosphoric or Sulphuric Acid, very weak and without fruit, but upright and of normal formation; without Iron, they remained very pale, weak and badly formed; and without Manganese, they did not reach their full strength and showed but a few flowers. Soda could not represent Potash in relation to the strength of the plants; Magnesia could not represent Lime. When, however, all of the mineral substances which vegetable life requires, were present in their proper proportion, and in sufficient quantity, the oat plant reaches a complete and pretty luxuriant development, even with an entire absence of Humus, or any vegetable substance in the experimental mixture.

The Relations which exist between Plants and the Soil, and the Manner in which these Relations influence the greater or less Fertility of the Soil.

In the preceding chapter we gave a knowledge of the soil, as far as it embraces its origin, and its consequent composition; we gave farther, the principles upon which the nutrition of plants is based; all that is now left for our consideration is an inquiry into the re-

lations which exist between plants and their soil, and in what manner these relations influence the productiveness of a soil for plants which may be cultivated upon it. These considerations may lead to the sure foundation of a useful, and thoroughly practical classification of soils, a knowledge, from which we are yet distant, which, however, it may be confidently hoped, will one day be reached by the united co-operation of practical farmers and chemists.

The soil consists substantially of two parts, of which the one constitutes almost its entire bulk, and through which we find the other, in small quantities, uniformly divided and diffused. The soil can be defined as the medium of the processes of vegetable life, and both of its parts, unequal as they are in their quantity, take nevertheless an equally important share in this function.

We have before observed that the bulk of plants consists of substances of organic form, composed of Carbon, Hydrogen, Nitrogen, and Oxygen, whilst only a small part of their constituents belongs to the mineral kingdom. This fact, compared with the composition of soils, will enable us to throw a light on the profound and wise manner in which nature has transferred the mediation of the processes of vegetable life to the soil.

We find that the constituents of the bulk of the soil do not directly participate in the nutrition of plants; that none of them is carried away by a crop, and their quantity therefore not diminished; but that the small quantity of substances which form the other part of fertile soils, and which are diffused through the bulk of the former, serve as nourishment for plants, and consequently diminish in soils by being cropped and carried away from them.

The functions which this latter part exercise on the mediation of the processes of life, consist, therefore, in supplying the plants with their necessary mineral constituents, and are perfectly and plainly understood.

The functions of the main part of soils therefore remain only to be considered, and we may judge a priori, that this part, if we abstract from it, its utility as a mass easily penetrated by the roots of plants, and thus capable of rendering them the necessary mechanical support,—is that which we have especially to assign as the medium of communication between the atmosphere and plants, and which therefore supplies them with Water, Carbonic Acid and Ammonia; for though the plants are in direct contact with the atmosphere, and, to a large extent, directly nourished from it by means of their leaves; they nevertheless depend, to the same extent, on the constituents of the atmosphere which, through their roots, enter the system. In the first period of their growth, e. g. they are solely referred to this latter manner of nutrition. These nourishments are therefore supplied to the roots, either by the air, (in its gaseous form as contained in the soil, or dissolved in rainwater, which falls on the earth and penetrates the soil,) or supplied by Humus in a manner as already explained.

These considerations must necessarily lead us to the conclusion that the nourishing properties of the soil also depend on its mechanical texture; for it is the particular kind of mechanical texture which causes a more or less perfect communication between the constituents of the atmosphere and the roots of plants, and which consequently furnishes a more or less perfect supply of Water, Carbonic Acid and Ammonia; and that therefore the fertility of soils is due to two factors: *to mechanical texture*, and *to directly nourishing properties.*

It has already been mentioned, that the bulk of soils consists of *quartz-sand* (including the fragments of undecomposed rocks,) and *Clay;* the latter being accompanied by smaller or larger quantities of Lime, Magnesia and Humus. On the different character, as well as on the respective quantitative proportions of these fundamental ingredients of soils, depends therefore the fitness of their mechanical texture for supporting vegetable life, viz: this is due to its water-retaining power; to its consistency in the wet and dry state; to its capacity to dry up more or less quickly; to its consequent contraction of volume, which gives rise to clefts and fissures tearing the roots; to the capacity to attract moisture from the atmosphere; the capacity of absorbing the atmospheric ingredients; to its power to warm itself and to retain the heat, &c.

Among the constituents of the soil, *Sand* has the greatest specific gravity, and forms therefore the heaviest part in soils; it has almost no water-retaining power; it gives consistency to soils only when in its finest state, and wet; it loses its moisture very quickly; it does not contract in volume by drying, nor does it attract moisture, or gases from the atmosphere, to any extent; and it has lastly, the greatest capacity of keeping heat.

The same is true of the *fragments of undecomposed rocks* which accompany the sand.

Clay, in its pure state, shows itself more or less in all these properties, as the opposite of Quartz-sand.

Humus aids in the water-retaining power of soils like Clay, without increasing however their consistency. The more a soil contains of Humus, the more clay it can contain, without becoming stiff and difficult to be ploughed. Humus farther prevents the rapid drying of soils, assists in attracting moisture and oxygen, also in keeping a constant temperature.

Lime and *Magnesia* take their place between Sand and Clay, aiding or tempering the properties of the one or the other.

In nature, we find these substances as constituents of soils, associated in such a manner, that we have on one side Quartz-sand, and the fragments of undecomposed rocks; and on the other, Clay, Lime, Magnesia and Humus, forming a kind of *Cement*, which envelops and connects the Quartz-sand particles, and is itself again loosened by them.

CHAPTER II.

FORMULA FOR MANUAL EXAMINATIONS WHICH WILL LEAD TO A CORRECT JUDGMENT OF THE DISTINCTIVE QUALITIES OF SPECIAL SOILS.—*Manner in which samples of soil must be taken for analysis—examination of the mechanical texture of the soil—determination of the quantity of Quartz-sand, and undecomposed fragments of rocks—of the quantity of Cement—of the character of the rocks—of the water-retaining power of the Cement—of the physical state of the Cement after drying—of the absorbent powers of the Cement for gases, and moisture, &c.—Examination of the directly nourishing properties of the soil—determination of Phosphoric acid—of Sulphuric acid—of Chloride—of Lime and Magnesia—of Silicic acid, Potash and Soda.*

We have tried in the preceding chapter to collect and exhibit general facts for a thorough *understanding* of the functions of soils, so far as they relate to the wants of plants; all that remains for this final chapter, is to give such a formula for manual examinations as will lead to a correct *judgment* of the quality of special soils. The method in which these examinations may be conducted, is distinctly dictated by our preceding considerations; we therefore have to act here in accordance with them; avoiding elaborate analyses, which, notwithstanding their troublesome performance, have shown themselves to be not of the greatest practical utility.

Before commencing the analysis of a soil, it is *first* necessary to observe that the sample was taken in the following manner:

With a clean spade a hole should be dug to the depth of the surface soil; and a slice of uniform thickness (about one inch) then be taken from the top to the bottom of the hole. This operation should be repeated in three or four different places on the *same kind* of soil; the different specimens thus obtained should then be mixed together, and about two lbs. of the mixture be put in a clean bag for analysis. Specimens of the subsoil should be taken in the same manner as those of the surface soil, special care being taken to prevent any mixture of the surface soil with it.

If the specimen of soil is not properly taken in the above manman, its analysis may prove nothing when done.

It is, *secondly*, necessary that the specimen is labeled with the name of the owner of the soil, and the State and county from which it was taken.

Thirdly and finally, should the specimen be accompanied by a note in which information is given, as to the location of the soil;

its productiveness; the crops which were taken from, and the manures which were applied to it, &c., &c.

Having made these preliminary remarks, we proceed to the

Examination of the mechanical texture of the Soil.

For this purpose, about three ounces of the soil are to be placed in a Beaker Glass, and washed with small and successive portions of hot water. The mass, well stirred, is to remain at rest for some time before the water is poured off, and a new portion added to it. This operation is to be continued until the wash-water runs off clear, thus effecting a perfect separation of the heavy particles of "quartz-sand and the fragments of undecomposed rocks" from the light mass of soils, to which we have applied the term "cement." The remaining particles, consisting of quartz-sand and undecomposed rocks, are then to be dried in the air, and weighed, and the weight noticed in per cent. I.)

This weight deducted from the whole weight of the soil taken, leaves the quantity of cement it contained, which has also to be noticed and expressed in per cent. II.)

The quartz-sand and rock particles are then submitted to an ocular examination with the aid of a microscope, III,) for the purpose of determining the rocks, from the degradation of which the soil was formed; and have to be preserved for future comparison.

The wash-water from the preceding operation has to remain at rest, until all of the cement has settled, which was held by it in suspension. The clear water is then poured off, and the cement after being well shaken, collected upon a filter. As soon as the water has ceased to drop from the filter, any portion (about 200 grains) of the contents of the filter may be taken and weighed in a platina dish on a delicate chemical balance. It is then to be removed to a closed water-bath where it has to remain for about one hour and a half, after which time it is again weighed and its loss calculated in per cent. IV,) which will express the water-retaining power of the cement.

Its physical state after drying must also be noticed, whether it presents a baked mass, divided by clefts and fissures, or a loose one easily falling to powder, V.)

It is then to be placed in an exsiccator—a room which is kept perfectly dry by means of concentrated sulphuric acid—and there remain for about four hours, after which time it is again weighed, and the increase in weight also calculated in per cent. VI,) which will express the absorbent power of the Cement for gases.

It may then be placed in the open air until it does not increase in weight any more, when it is again weighed, and the increase in weight calculated in per cent. VII,) which will express the absorbent power of the cement for moisture.

The factors II, IV, V, VI, VII, to which must also be added the specific gravity of the cement, VIII,) disclose all the peculiarities of the cement as far as they refer to its action as a constituent of soils, and if compared with the weight and character of the quartz-sand particles and their associates (undecomposed rocks,) as determined by I and III, will result in a perfect understanding of the physical state of the soil. These factors have to be noticed in a tabula arranged for the purpose; and each new analysis of soil, noticed in the form of these factors, will extend this tabula, and thus enlarge the knowledge of the chemist so far, that he may soon acquire the principles of a general and thoroughly practical classification of soils

Though these factors give an entirely satisfactory account of the action of the different substances which constitute the bulk of soils, it is notwithstanding often desirable to know the exact quantity of humus which is present.

To determine the quantity of humus, about 150 grains of the soil are to be boiled for some time in dilute potash liquor, additions of water being made to it from time to time as evaporation takes place. By these means all the humus is dissolved, forming a dark brown liquor, which is to be filtered from the insoluble residue, and treated with dilute hydrochloric acid, until it becomes slightly acid. The humus is then precipitated, and must be collected upon a weighed filter, washed, dried at 266 F., and weighed; the resulting weight is that of the humus of the soil minus the weight of the ashes which are left after burning it. The average quantity of ammonia which humus can produce is one-seventh of its weight, and can be recognized by its smell either when the humus is heated by itself, or still better when heated with soda lime.

Examination of the directly nourishing properties of soils.

We have already explained that the directly nourishing properties of soils depend on the presence and respective quantities of phosphoric acid, sulphuric acid, chlorine, silicic acid (silica in its soluble modification,) lime, magnesia, potash and soda, which are diffused through the bulk of soils in form of alkaline, or earthy salts. All of them are more or less easily soluble in water, and therefore uniformly diffused through the soil.

For the purpose of extracting them from soils, chemists are very apt to treat soils with water, and to think that the result of analysis of the so procured extract would represent that quantity of nourishing substances in soils, which will benefit the plants for the present. This is however not the case; we cannot imitate all the influences which nature during a whole season exercises upon these substances, by treating them for some hours with cold or hot water

in our laboratories. The water which falls to the earth is also quite another kind of water from that which the chemist uses; it not alone assumes power by its fall, it is also freshly impregnated with the constituents of the atmosphere: carbonic acid, oxygen and ammonia, substances which very much aid, either directly or indirectly, in dissolving the nourishing ingredients of soils. The water of which the chemist can dispose has lost already most of these substances, and, when boiled, even loses them entirely. Besides, we know that the better the adaptation of a soil for the purpose of cultivation, so much the longer will it retain its nourishing ingredients, and proportionably resist their loss by the action of water. A really good soil may therefore, mutatis mutandis, yield less quantities of nourishing substances to water, than one of an inferior quality.

Water acts principally as an acid and, most especially when impregnated with carbonic acid and oxygen, as is the case with rain-water. The best way to imitate nature when extracting from soils their nutrient ingredients, seems therefore to remedy the deficiencies of pure water by the addition of an acid, and this is the method which we have adopted.

Determination of Phosphoric Acid.

Of the different methods of the determination of Phosphoric Acid, that by which Phosphoric Acid is detected by molybdate of ammonia, is distinguished, as the most advantageous for application to soils, furnishing indisputably the most exact results of all, and requiring besides little skill, and the least time.

As to the preparation of the molybdate of ammonia, it is most commonly made from the natural Sulphuret of molybdenum. This is to be pulverized, or on account of its toughness ground to powder and then, whilst being exposed to the air, heated and constantly stirred; Sulphurous acid will then escape, and molybdic acid be left behind. To prevent the melting, or the escaping of the latter, the heat must be moderate, most especially towards the end of the process. The residue is digested for some time with ammonia, which dissolves the molybdic acid, whilst undecomposed sulphuret of molybdenum, quartz and other substances remain. The filtrate evaporated, and if necessary, once more filtrated, then boiled and mixed, whilst yet hot, with strong ammonia, will, by cooling, leave crystals of molybdate of ammonia.

A concentrated solution of these crystals in water furnishes the above mentioned re-agent.

The effect of molybdate of ammonia on phosphoric acid and its salts, in a solution which has been acidulated by nitric acid, manifests itself, first, in the forming of a white precipitate of molybdic acid, which is re-dissolved, however, in the excess of the nitric

acid present. The liquid then assumes a yellow color, and deposits a yellow precipitate of a crystalline structure, the formation of which is accelerated by heating.

This precipitate consists of about three per cent. of phosphoric acid, a very small quantity of ammonia, and, the rest, of molybdic acid, which are united to each other in a manner yet doubtful. It is easy soluble in ammonia ; and also in an excess of phosphates ; insoluble, however, in hydrochloric and nitric acids.

These conditions demonstrate at once, that the application of this method, is especially adapted to the tracing of small quantities of Phosphoric Acid as in soils. In this case no excess of phosphates, in which the form precipitate could be dissolved, is to be feared, nor any danger in overlooking a precipitate, which consists almost entirely of substances used for precipitation, with only a small portion of the substance which is the object of search.

Direct experiments to test the sensibility of this re-agent were made, and the following results obtained.

By dissolving 5 grammes of crystallized phosphate of soda, which contain 1 gramme of Phosphoric Acid, in 25 grammes of water, a solution was obtained, which contained in all its parts 1-30 of its weight of Phosphoric Acid.

With this normal liquid, different other solutions were then made, by diluting the former with water and a suitable quantity of nitric acid ; the respective quantities of Phosphoric Acid in which were 1-300, 1-3000, 1-6000, 1-12000, 1-24000, 1-48000, 1-96000, 1-192000.

After molybdate of ammonia being added, and the whole heated, 1-48000 or 1-50000 of the dilutions created a distinctly visible precipitate. The 1-96000 dilution formed after a few days a little precipitate which did not appear at the 1-192000 dilution.

Experiments performed in the same mode, differing only with regard to the normal liquid, which was in this instance diluted with a concentrated solution of a soil, in nitric acid, (the soil did not contain any appreciable quantity of Phosphoric Acid) instead of acidulated water, led exactly to the same results, viz : 1-48000 or 1-50000 dilution caused immediately a distinct precipitate ; 1-96000 after a few days ; 1-192000 none at all.

Organic matter, iron clay, lime, and all those substances, which are extracted by the aid of nitric acid from soils, had exercised not the least influence on this reaction.

After these remarks, the last but most important point to be considered is finally the manner in which the above mentioned results of observations can be applied for the recognition and the quantitative determination of Phosphoric Acid in soils, as distinctly as the farmer needs knowing it.

The solution of this point leaves now hardly any difficulties.

We know by analyses of Gregory, Way, Boussingault and Liebig, that a wheat crop of 32 bushels at 62 lbs. contains of:

Grain 1,984 lbs. containing	Phos.	Acid,		19.0lbs.
Straw 3,360 lbs.	"	"	"	5.4 lbs.
Chaff 400 lbs.	"	"	"	2.1 lbs.
Total amount of Phosphoric Acid				26.5 lbs.

If we now take a crop of 32 bushels at 62 lbs. for an average crop, which a wheat soil ought to produce, and to which any wheat soil can be improved, then it is necessary as above mentioned, that it must contain 26.5, or we will say 30 lbs. of Phosphoric Acid, if it shall be able to produce the above crop.

The weight of an average acre of soil one foot deep, is 3000 tons, according to the mean specific gravity of 16 varieties of soil, dried in the air, which was 2.44, as ascertained by Dr. Krocker.

These two statements show us at once the way in which soils ought to be treated for detecting the presence, and at the same time the approximate quantity of Phosphoric Acid in them.

If 3000 tons, or 6,000,000 lbs. of soil, (one acre) ought to contain 30 lbs. of Phosphoric Acid to produce a fair crop of wheat, then every part of this mass ought to contain 1-200.000 of Phosphoric Acid. Or if we dissolve the Phosphoric Acid in a certain quantity of this mass by a solvent of equal weight, the solution obtained will also contain 1-200.000 of Phosphoric Acid; or by evaporating the same to 1-4, a solution will be obtained which contains 1,50.000 of Phosphoric Acid, an amount which can be detected by molybdate of ammonia, as above stated.

For the analysis of soils, the most convenient quantity to be taken is about 3-4 of a pound, which is to be treated with the same quantity of water, acidulated with nitric acid and then heated in a water-bath for about an hour.

For the purpose of testing a soil for its sufficiency or deficiency in Phosphoric Acid, a certain portion of the filtered solution of the soil is to be evaporated to one-fourth, (an excess of Nitric Acid being present) and then tested with Molybdate of Ammonia.

If a visible precipitation takes place, then 30 lbs. of Phosphoric Acid at least exists in the examined soil; 60 lbs. of Phosphoric Acid if evaporated to one-half; 90 lbs. of Phosphoric Acid if evaporated to three quarters; 120 lbs. if not at all evaporated, &c.

Determination of Sulphuric Acid.

For the determination of Sulphuric Acid we can apply a still finer and more sensible re-agent than even for that of Phosphoric Acid. Experiments which were made on this subject resulted in the observation, that in a solution of sulphate of soda which contained but 1-100.000 of its weight of sulphuric acid, a drop of a concentrated solution of Nitrate of Baryta still produced a precipitate of sulphate of Baryta, which by heating quickly settled to the bottom in the form of plainly visible white grains, insoluble in acids, and not altered at all by the presence of organic matter, or such others as may be extracted from the soil by acids.

We also know by analyses of Boussingault and of Fresenius, that a potato crop of 10 tons contains

Tuber 10 tons, containing	of	Sulph.	Acid	30 lbs.
Top 2 "	"	"	"	10 lbs.
Total amount of Sulphuric Acid				40

If we now take a crop of 10 tons as an average crop per acre, then it is necessary that the soil contains at least 40 lbs. of sulphuric acid (equal to one bushel of plaster of Paris,) if it shall be able to produce the above crop.

We have further to remember that the average weight of one acre of soil, one foot deep, is 300 tons—6,000.000 lbs.

6,000.000 lbs. of soil ought therefore to contain 40 lbs. of sulphuric acid to produce the average crop of potato, and consequently every part of this mass 1-150.000 of its weight of sulphuric acid.

Or if we dissolve the sulphuric acid in a certain quantity of the above mass, by a solvent of equal weight, the solution obtained will also contain 1-150.000 of sulphuric acid; or by evaporating from it one-third, a solution will be obtained which contains 1-100.000 of sulphuric acid, an amount which can be detected by Nitrate of Baryta, as above stated.

For the purpose of testing a soil for its sufficiency or deficiency in sulphuric acid, it is therefore only necessary to take a certain portion of the prepared solution of the soil to evaporate from it one-third, and then to test with Nitrate of Baryta. If no precipitate occurs after heating the liquid, it is a proof that the soil is deficient in sulphuric acid.

Determination of Chlorine.

For the detection of chlorides, we are also favored with a reagent which distinguishes itself by its sensibility. Experiments which were made to try its sensibility, have resulted in the ob-

cess of ammonia and phosphate of ammonia; filter from the formed precipitate, evaporate the filtrate to about one-half, and whilst yet hot, add to it first acetate of lead, and then carbonate of ammonia and ammonia. To the filtrate, add a little sal-ammoniac, evaporate and apply finally a gentle heat to expel the ammoniacal salts. The remaining consists of Chloride of Potassium and Chloride of Sodium, which have to be weighed and separated by Chloride of Platinum in the common way. Potash is among these substances indisputably the most valuable, and is always accompanied by Soluble Silicic Acid. To Soda we cannot attribute equally valuable nourishing properties, since it has been found that it makes a constituent of plants, the quantity of which contained in them diminishes in proportion to their cultivation. It always indicates its presence in soils by the presence of Chlorine, and is also supplied in its combination with Chlorine. The result of analyses made by Boussingault and Fresenius may finally give an idea how much of Potash, Soda and Silicic Acid, is removed from one acre by a potato crop:

	Potash.	Soda.	Silicic Acid.
Tuber 10 tons, contain of	110	7	11 lbs.
Top 2 " " "	4	2	60 lbs.
Total amount of	114	9	71 lbs.